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The works of the Lord are great, sought out of all them that have pleasure therein.—Ps. cxi, 2.

THE SIDEREAL MESSENGER.

FEBRUARY, 1891.

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DIRECTOR OF CARLETON COLLEGE OBSERVATORY.,

NORTHFIELD, MINN.

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THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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ON WOLF AND RAYET'S BRIGHT-LINE STARS IN CYGNUS.

WILLIAM HUGGINS D. C. L., LL. D., F. R. S., AND MRS. HUGGINS.

In 1867 MM. Wolf and Rayet discovered at the Paris Observatory three small stars in Cygnus, which in the spectroscope showed several bright lines upon a continuous spectrum.* All three stars have a very bright band in the blue part of the spectrum.

These stars are:—

B.D. + 35°, No. 4001.
B.D. + 35°, No. 4013.
B.D. + 36°, No. 3956.

Their spectra were described in 1873, by Vogel, whose observations agree substantially with the original description given by Wolf and Rayet.† A more complete account of their spectra was given by Vogel in 1883, from observations at Vienna with the 27-inch refractor made by Sir Howard Grubb.‡

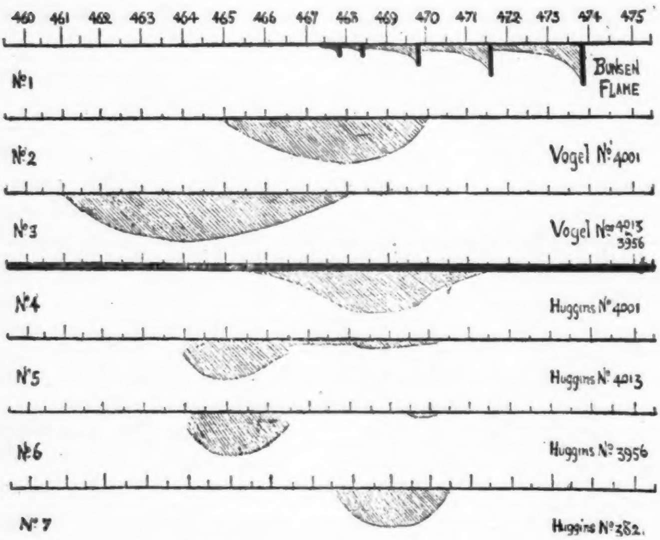
Vogel's measures of the bright blue band place it in the star No. 3956 at from λ 468 to λ 461, with a maximum at λ 464; in the star No. 4013 with a maximum at the same place in the spectrum; while the corresponding blue band in the star No. 4001 has a considerably less refrangible position, commencing at λ 470, reaching a maximum at λ 468, and ending about λ 465.

These later measures, though they differ from his earlier ones, in so far as they show that the blue band has not an identical position in all three stars, nevertheless support substantially his earlier observations, which Vogel considered to show, contrary to the statements of Secchi, that

* 'Comptes Rendus,' vol. 65, 1867, p. 292.
† 'Berichte K. Sächs. Ges. der Wiss.,' Dec. 1873, p. 556.
‡ 'Publicationen Astrophys. Obs. Potsdam,' vol. 4, No. 14, pp. 17-21.

the bright lines, including the blue band, were not due to carbon.

In the diagram, Nos. 1, 2, and 3 show the positions of the bright bands in the three stars, according to Vogel's measures, relatively to the blue band of the hydrocarbon flame.



Vogel's measures are:—

	Beginning of the band.	Brightest part.	End of the band.
Star No. 4001........	λ 470	λ 468	λ 465
" 4013........	—	λ 464	—
" 3956........	λ 468	λ 464	λ 461

His diagram shows the band in No. 4013 to begin and end at about the same positions as in the star 3956.

It has been stated recently, that the bright blue band in all three stars is the carbon band in the blue commencing near λ 474*; and more recently, notwithstanding the difference of position, according to Vogel, of the band in one of

* 'Professor Lockyer, in the Bakerian Lecture for 1888 (Roy. Soc. Proc., vol. 44, p. 57), says of the star No. 4001:—" The bright band with its maximum at λ 468 is the bright carbon fluting commencing at λ 474 and extending towards the blue, with its maximum at 468, as photo graphed at Kensington."

the stars from that which it occupies in the other two of as much as λ 0040, that direct comparisons showed an absolute coincidence of the band in all three stars with the blue band of a spirit-lamp flame.*

As the presence or absence of carbon in these stars, as shown by the coincidence or otherwise of the blue band with that of the hydro-carbon flame, was of great importance to us in connection with a wider investigation on which we are at work, we thought it necessary, after these recent statements as to the position of the band, to make direct comparisons of the spectra of these stars with that of the hydrocarbon flame under sufficiently large dispersion to enable us to determine whether Vogel's measures are substantially correct, or whether they are so largely in error as the absolute coincidence of the band with the blue band of a spirit-lamp flame in the case of all three stars would show them to be.

The obvious importance of making the observations with sufficient dispersion is supported by Vogel's own experience. With the small dispersion which he employed in his earlier

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Of the star 4013:—"The bright band in the blue at 473 is most probably the carbon band bright upon a faint continuous spectrum, this producing the absorption from 486 to 473" (*loc. cit.* p. 41).

Of the star No. 3956:—"The bright band at 470 is the carbon band in the blue, commencing at 474, with its maximum at about 468, as observed and photographed at Kensington" (*loc. cit.* p. 43). See Vogel's measures for the band in this star, which are given in the text.

Diagrams of the spectra of these stars are given at pp. 38, 40 and 41, based on Vogel's observations and his curves, which, on a slightly reduced scale, are placed at the bottom of the diagrams. The maximum of Vogel's curves is placed in all three diagrams at λ 468, and agrees in the diagrams with the carbon band, whereas Vogel's original curves and his measures place the maximum in the case of two of the stars at λ 464, beyond the carbon bands.

* Professor Lockyer, in a signed article in 'Nature' (August 7, 1890, vol. 42. p. 344), writes:—

"In the Bakerian Lecture for 1888 I gave a complete discussion of the spectra of bright-lined stars, as far as the observations went, and the conclusion arrived at was that they were nothing more than swarms of meteorites a little more condensed than those which we know as nebulæ. The main argument in favor of this conclusion was the presence of the bright fluting of carbon which extends from 468 to 474. This standing out bright beyond their short continuous spectrum gives rise to an apparent absorption band in the blue. . . . Direct comparisons of the spectrum of all the three stars in Cygnus with the flame of a spirit-lamp have been made by Mr. Fowler, and these showed an absolute coincidence of the bright band in the stars with the blue band of carbon seen in the flame. It was found quite easy to get the narrow spectrum of the star superposed upon the broader spectrum of the flame so that both could be obobserved simultaneously."

observations in 1873, he did not detect the large difference of position, about λ 0040, of the band in No. 4001, as compared with its position in the other two stars. On this point Vogel says, in his memoir of 1883:—"Etwas abweichend ist nur die Auffassung der Lage der breiten hellen Bande im Blau, die bei den früheren Messungen bei allen drei Sternen übereinstimmt. . . . Bei den verhältnissmässig geringen optischen Hülfsmitteln, mit denen jene Messungen ausgeführt wurden, ist die Uebereinstimmung aber eine ganz überraschande" (*loc. cit.*, p. 21.)

We observed the spectra of the stars successively, first with a direct vision prism of small dispersion, then with a spectroscope (A) containing one prism of 60°, and finally with a spectroscope (B) with two compound prisms, equal to about four prisms of 60°; with the last-named instrument the comparisons with the hydrocarbon flame were made.

A rapid preliminary comparison in the spectroscope (B) of the spectra of the three stars with the blue base of a Bunsen flame showed at once the substantial accuracy of Vogel's measures, and the striking difference of position of the band in the star No. 4001 from that which it holds in the other two stars.

The obvious want of agreement of the star bands with the blue band of the Bunsen flame was seen at once. Their relative positions appeared to agree substantially with the positions represented in No. 2 and No. 3 of the diagram, which are based on Vogel's measures. More careful and repeated observations brought out clearly, as is indeed shown by Vogel's curve, that the star bands differ in character as well as in position from the blue band of the hydrocarbon flame, and also in some respects from each other.

Before giving in more detail the results of our observation on each of the three stars, it should be stated that in all the stars the continuous spectrum is not in our instruments a short one, ending before the position of the bright blue band is reached. On the contrary, an examination with all three spectroscopes showed that the continuous spectrum, though enfeebled by absorption a little before reaching the blue band, can be traced, as is shown in Vogel's curves, quite up to the band, and indeed extends for a long distance

into the violet beyond the blue band. The blue band does not in our instruments stand out bright beyond the end of a short continuous spectrum, but falls upon a fairly luminous continuous spectrum, which can be traced past the blue band into the violet, apparently as far as the eye could be expected to follow it.

We suspected bright lines or bands in the region more refrangible than the blue band, but in such faint objects this is a point which should be determined by photography.

Professor E. C. Pickering has since kindly informed us that his photographs of the star No. 4001, which extend into the ultra-violet region, show beyond the blue band the bright hydrogen lines at 434, 410, 397 and 389; and also other bright lines at 462, 455, 420, 406, 402, 395 and 388.

In his photographs of the stars 4013 and 3956, however, the only well-marked line is in the blue at 470.

Star 4001.—In this star, as is shown by Vogel's measures and curve, the bright blue band is less refrangible than in the other two stars, and approaches therefore nearer to the position of the blue band of the hydrocarbon flame. The appearance and position of the band in the star as contrasted with that of carbon, when observed in spectroscope B, are represented in spectrum No. 4 of the diagram.

The brightest part of the band, from about λ 468 to λ 469, falls off rather suddenly in brightness at about these wavelengths, but can be traced toward the red as far as about λ 471.5, and as far in the blue as about λ 465.5.

In our observation of this and the other stars we did not attempt micrometric measures of the blue band, but we estimated their positions by means of the intervals between the five flutings of the band of the Bunsen flame. In the case of objects so faint in our instrument when viewed under the dispersion of spectroscope B, we did not consider there would be any real gain of accuracy by attempting to take measures.

Though the wave-lengths assigned to our positions must therefore be regarded as not more than approximately correct, we have no hesitation in considering them fully accurate enough for the purpose of our investigation.

The star band is not split up into well-separated maxima, as is the Bunsen flame band, but we have little doubt that

the brightest part of the band, from λ 468 to λ 469, which is much, and rather suddenly, brighter than its beginning and termination, consists of bright lines. Lines appear to flash out at moments, but in our instruments they cannot be seen with sufficient steadiness for us to be sure of their number and position.

Under certain conditions of the electric discharge, the normal relative brightness of the component flutings of the blue hydrocarbon band has been observed to be so far changed that the position of maximum intensity is moved from the less refrangible end of the band towards the blue end; but the five flutings remain without any change of their position in the spectrum.*

Dr. Hasselberg, by means of feeble disruptive discharges from tinfoil terminals placed outside an exhausted tube containing vapor of benzole, obtained a nearly pure spectrum of the order of that in a hydrocarbon flame mixed only with faint lines of hydrogen. He says: "Es war aber hier die violette Gruppe sehr schwach. Dagegen schein mir die blaue Gruppe relativ heller als im Flammenspectrum, und sie hatte ausserdem entschieden ihre grösste Intensität nicht an der weniger brechbaren Kante, sondern mehr nach dem Violettenhin. Dasselbe schien mir auch mit der gelben Gruppe der Fall zu sein. In Bezug auf die grüne Gruppe konnte ich aber keine Verschiebung des Intensitätsmaximums bemerken."

Dr. Hasselberg gives curves to show the amount of this change of intensity in the blue group and in the orange group. In the blue group the maximum is moved from the first to the third line, that is, about λ 4698. His curve gives the brightness of the maximum over that of the first lines as about 7 to 6, whereas the normal relative intensity of these two lines is in the inverse direction and as about 2 to 4 (Watts, 'Index of Spectra,' p. 30).†

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* It is necessary to state that the maximum luminosity of the blue band, under some conditions, is about 468. . . . The conditions under which this band has its maximum luminosity at 468 in Geissler tubes seem to be those of maximum conductivity. If the pressure be high, all the members of the group are sharp, and the luminosity of the band is almost uniform throughout. This always occurs when the pressure is very low. At intermediate stages of pressure, however, the luminosity has a very decided maximum at about 468" (Appendix to the Bakerian Lecture for 1888, 'Roy. Soc. Proc.,' vol. 45, pp. 167, 168).

† 'Mém. de l'Acad. Imp. des Sciences de St. Pétersbourg,' vol. 22, No. 2, 1880, p. 82.

A similar change from the normal relation of brightness of the flutings within the band, even if removed to λ 468, does not seem to us to bring the star band sufficiently into accordance in character and position with those of the band of the hydrocarbon flame to justify us in attributing the blue band in the star to carbon. Though we traced the band a little further towards the red, than the position of the beginning of the band given by Vogel's measures, yet it is very faint, and without any increase in brightness at the place of the second fluting of the carbon band, beyond which we were unable to see it.

According to Hasselburg's curve, the second bright fluting, where in our instruments the star band ends, still retains a brightness of about $\frac{1}{12}$ of that of the maximum, and the first line, at the position of which no brightening of the feeble continuous spectrum of the star could be detected, a brightness of about $\frac{6}{7}$ of that of the maximum. That the flutings of the band were not obscured by the absorption band at this part of the spectrum appears clear from the circumstance that we could trace the faint continuous spectrum up to the bright band.

Vogel's and our observations agree in making the band run on some distance beyond the visible termination of the blue band of the Bunsen flame. Piazzi Smyth, under some conditions, observed a large number of faint "linelets," beyond the "5th leader" of the band, where its visibility usually ends; and in the brilliant light of the arc the band can be traced further in the blue. The extension of the band under such circumstances does not seem to us to affect our present argument; for in the very feeble light of the star we may surely take it that the carbon band, if present, could not be seen, to extend further than its usual visible limit in a Bunsen flame, namely about λ 468.

Perhaps it should be stated in connection with the circumstance that we saw the band extend a little further towards the red than Vogel did, that at the time of our observations the hydrogen line at F was not visible in our instruments, whereas it was bright at the time when Vogel observed the star. In the spectrum of a similar star, D. M. + 37° 3821, in which the hydrogen line at F at the time was bright, the blue band was seen by us to stop near the place given by Vogel in his measures of the star No. 4001.

Not only is there no coincidence, so far as Vogel and we have observed, of the position of the band in the star with that of the blue band of the Bunsen flame; but, further, the want of accordance of its general characters is so great as to make the view that its origin is carbon very improbable. This improbability is very greatly increased when we find, as will be shown presently, that no traces whatever of the very bright beginnings of the more brilliant green and orange bands could be detected by us in any of the stars. Further, Professor E. C. Pickering has kindly sent to us an account of his photographs of this star, which, though they show the hydrogen line at λ 434, do not exhibit any brightness at the positions of the indigo hydrocarbon bands, beginning near 4312, and λ 4382.

This star, however, can scarcely be taken by itself; in the case of the other two stars, in the spectra of which, according to Vogel's, Copeland's, and our own observations, the brightest part of the blue band is from λ 464 to λ 465, but nearer λ 465, quite outside the ordinary visible limit of the carbon band, the evidence seems very strong indeed that the band does not owe its origin to carbon.

We satisfied ourselves that when the spectrum of the star is examined under the dispersion of spectroscope B, none of the brighter parts of its spectrum fell at, or very near, the green, orange, and indigo flutings of the hydrocarbon flame spectrum; at these positions we were unable to detect any sensible brightening of the star's spectrum. Professor Copeland's measure of the blue band in 1884 was λ 469.5.

No. 4013.—Vogel does not give measures of the beginning and the ending of the band in this star, but only of the brightest part:—"Hellste Stelle, nahezu Mitte, einer breiten verwaschenen Bande, λ 464." He gives, however, a diagram of the spectrum in which the bright blue band is represented as substantially coincident in position and in general character with that in the spectrum of No. 3956.

Our observations agree substantially with those of Vogel, but they make the band to consist of two parts, a very bright part, from about λ 466 to λ 464, but brightest near λ 465; and a very faint band, apparently detached from the bright one from about λ 4685 to about λ 4705. This faint band is brightest near where it ends rather abruptly at the

more refrangible end. The very bright band has not the character of a fluting, nor is it broken up into maxima widely separated like those of the Bunsen flame band, but appears to be a group of bright lines. The lines were only glimpsed at moments; it is therefore difficult to make a drawing which truly represents the character of the band as seen in our instruments. The band which is shown at No. 5 of the diagram is left unfinished at the more refrangible end, as we were not certain how far we ought to consider it to extend.

In this star (as we shall show to be the case in No. 3956 also), the great body of bright radiation lies far beyond the ordinary visible limit of the blue carbon band, and no connection whatever with carbon is even suggested to us by the star's spectrum. Dr. Copeland's measure of the band in 1884 was λ 465.4.

The continuous spectrum of the star is unequally bright from the presence of bright groups and also apparently of absorption bands or lines, and therefore with small dispersion it might be easily supposed that the spectrum is brighter at the position of the green carbon band. We examined the continuous spectrum repeatedly with great care, and we were able to satisfy ourselves that, under the considerable dispersion of our instruments, there was no sensible brightening of the spectrum at the positions of the green and of the orange bands of the Bunsen flame.

No. 3956.—Vogel places the brightest part of the band in this star at the same position in the spectrum as in the star last considered, No. 4013, namely, at λ 464, a position beyond the carbon band. The position of the band as it appeared in spectroscope B with the third eye-piece, is represented at No. 6 in the diagram. The position of the band relatively to that of the Bunsen flame was determined by estimations made by means of the intervals between the bright flutings of the Bunsen band. The position agrees substantially with that given by Vogel, but places the maximum brightness nearer to 465. This bright part probably consists of a group of bright lines and falls off rather suddenly at both ends. We were not certain if the light beyond this bright part was due to a continuation of the band or to continuous spectrum, more or less dimmed by absorp-

tion; we have, therefore, left the ends of the band incompleted in the diagram. Copeland's measure of this band in 1884 was λ 464.9.

The sub-band seen in the star No. 4013 is very much fainter in this star, but we have little doubt that there is a very faint band present at about the same place in the spectrum.

Professor E. C. Pickering has found in the near neighborhood of these three stars other stars possessing bright lines in their spectra.* The brightest of these, independently discovered by Dr. Copeland in 1884,† namely, D. M. + 37° 3821, in which the spectrum is similar to that of the Wolf-Rayet stars, was examined. Dr. Copeland says of this star: "It has a spectrum of several bright lines near D, and a very bright band in wave-length 464" (*loc. cit.*). We were therefore surprised to find the blue band, which is very brilliant, not in the position of the band in the stars No. 4013 and No. 3956, but less refrangible, corresponding to the position of the band in the star No. 4001.

The bright line begins about λ 467 and runs on to nearly λ 470.5. It is clearly not made up of flutings similar to those of the Bunsen flame, but is a group of lines nearly uniformly bright throughout the length of the band. The band did not appear to extend in our instruments towards the red quite so far as the band of No. 4001; it stops near the place assigned by Vogel to the beginning of the band of No. 4001.

The band is represented in spectrum No. 7 in the diagram. Direct comparison with hydrogen showed that the line at F is brilliant in this star.

After some scrutiny of this part of the star's spectrum, we became conscious of a very feeble brightening of the spectrum beyond the bright band towards the violet, and as far as we could estimate its position, at about from λ 464 to λ 467, that is to say, about the position assigned to the band by Dr. Copeland in 1884.

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* "The following list contains the designations of all eight stars (with bright lines), the first four being those previously known:—35° 4001, 35° 4013, 36° 3956, 36° 3987, 37° 3821, 38° 4010, 37° 3871, 35° 3952 or 3953. Of these 37° 3871 is P. Cygni, and 37° 3821 is the star in the spectrum of which the bright lines are most distinct" (letter in 'Nature,' vol. 34, p. 440).

† 'Monthly Notices, R. A. S.,' vol, 45, p. 91, 1884.

We then re-examined the spectrum of No. 4001, and were able to feel pretty sure that a similar faint brightening of the spectrum occurs in this star also at the same place, namely, about the more refrangible position of the blue band in the stars No. 4013 and No. 3956.

Dr. Copeland, during his travels in the Andes in 1883, observed γ Argûs and five small stars with bright lines in their spectra. He says: "As far as my measures and estimates go, all of them belong to the same class as the three Wolf-Rayet stars in the Swan, to which Professor Pickering has since added a fourth outlying member."*

Dr. Copeland gives the position of the bright blue band in γ Argûs as λ 464.6.

Among the stars in the great cluster G. C. 4245, near ζ Scorpii, Dr. Copeland found a star, P. XVI 204 = Stone 9168, which has a similar spectrum, namely, with a bright band in the blue and two in the yellow. He found the position of the blue band to be λ 465.1.

In the case of two other small stars with similar spectra, he found respectively for the blue band the approximate measures, λ 463.3 and λ 463.6.

These four stars were similar, therefore, at the time of the observations to No. 4013 and No. 3956, in which the maximum of the blue band is not far from λ 464, and therefore outside and beyond the ordinary visible limit of the blue carbon band.

Professor Vogel observed two other stars with similar spectra, of which the main feature is the very bright band in the blue region, namely, Arg. Oeltzen 17681 and Lal. 13412. These stars are too low in southern declination to be reached from our Observatory.

Vogel places the blue band in Lal. 13412 at λ 469, which shows that it has a position similar to that of No. 4001 and of Dr. Copeland's star. In the case of Arg. Oeltzen 17681 Vogel makes the band to extend through about the entire range of refrangibility occupied by the two positions of the blue band in the Wolf-Rayet stars according to his measures of them, namely from λ 461 to λ 470, with a maximum at the place where they would overlap, namely, λ 466.

* "An account of some recent Astronomical Experiments at High Elevations in the Andes;" 'Copernicus,' vol. 3, 1883.

Let us consider the four stars with an intensely brilliant blue band which we have examined; in two of them the band extends from about λ 464 to λ 467, and in the other pair the band has a less refrangible position, from about λ 466 to λ 471, but there is also in the case of each pair a very faint band visible, or suspected, at the position of the blue band in the other pair. Further, in Arg. Oeltzen 17681, Vogel found the bright band sufficiently long to include both positions of the band.

One suggestion which presents itself is whether these bands, or, more correctly, these groups of bright lines, may be variable, so that, under certain conditions one or other of them becomes brilliant. Such a state of things would reconcile our observations of + 37° 3821 with the earlier measures of Dr. Copeland, and, indeed, might possibly explain, if this variability should be established, the circumstance that so accurate an observer as Professor Vogel did not detect, even with his smaller instrument in 1873, the very large difference of position of the band in 4001 from that of the corresponding band in the stars 4013 and 3956, which was so conspicuous in 1883, and is so still at the present time. In the broad characters of their spectra, and in their magnitudes, the Wolf-Rayet stars have remained unchanged since the discovery of their remarkable spectra in 1867.

As the only direct evidence of such a variability rests upon the change of position of the band in Dr. Copeland's star since his observation in 1884, I wrote to Dr. Copeland to ask if his position rested upon sufficiently accurate measures, or was arrived at by estimation only. In reply he says: "The place of the blue line (rather band) in D. M. + 37° 3821, given in the 'Monthly Notices,' is a mere estimate to show the character of the star."

Whether any change of position of the band has taken place must therefore remain at present uncertain; but independently of any such direct evidence of variability, the two positions of the very bright blue band, with the suspicion of faint bands at the alternate positions, appear to us suggestive of possible variation, especially when we consider that the spectra of these stars consist of numerous absorption bands and groups of bright lines upon a feeble continuous spectrum, a character of spectrum which seems to point to

a probably unstable condition of the atmospheres of these stars. The large difference of position of the bands in the two groups of stars is much too great to admit of an explanation founded upon a possible orbital motion of the stars. Besides the near coincidence of Dr. Copeland's measures of two bright lines common to the stars 4001 and 4013 shows that the difference of position of the blue band is not due to motion in the line of sight.*

If future observations should show that the bright blue groups are variable, we must look, it would seem, to causes of a physical or a chemical nature.

If the two bright groups, differing in position by about λ 0040, belong to different substances, or, less probably, perhaps, to different molecular conditions of the same substance, it is conceivable that one or other substance or molecular state, may predominate and appear brilliant, according to certain unknown conditions which may prevail in the stars' atmospheres.

It might be suggested that both bands are due to a long group of bright lines extending from about λ 461 to λ 471, and that this long group is cut down by absorption bands; in one pair of stars an absorption from the green cuts off the less refrangible part of the long group down to about λ 467, while in the other two stars the more refrangible part is eclipsed, and the bright group appears as in 4001.

The appearance of the spectra in our instrument scarcely seems to us to be in accordance with such a view, because, though we did suspect brightenings in the alternate places, the appearance of the spectrum was not such as to suggest a bright group dimmed by absorption, for in that case the amount of absorption needed to all but obliterate a group, as bright as it appears in the other pair of stars, would have blotted out completely the relatively feeble continuous spectrum. This continuous spectrum, though faint, was still distinctly seen.

* Dr. Copeland permits me to give the following measures of the bright lines in the Wolf-Rayet stars which were made by him and Mr. Lohse on January 28, 1884.

Star.	1st yellow line.	2d yellow line.	Bright line.	Faint line.	Large blue band.
+ 35° 4001......	—	—	541.2(3)	522.0(1)	469.5(3)
+ 35° 4013......	582.4(2)	568.9(2)	541.0(2)	—	465.4(2)
+ 36° 3956......	581.0(2)	570.4(2)	—	523.3(1)	464.9(2)

More observations are needed, but it appeared to us desirable by these suggestions to invite the attention of observers to the points in question.

As the main object of our examination of these stars was to determine whether the bright band in the blue was to be regarded as showing the presence of carbon by its coincidence with the blue band of the hydrocarbon flame, we were not able from the pressing claims of other work, to extend our examination to many other points in connection with the spectrum of these faint stars, for an exhaustive examination of which, indeed, our instruments are not sufficiently powerful.

We have stated already that the fairly luminous continuous spectrum reaches up to the bright band in all three stars and extends beyond into the violet, as far as the eye could be expected to follow it.

The spectra are weakened at many points by what appear to be absorption bands, and are crossed by several brilliant lines, the positions of some of which have been given by Vogel and by Copeland.

An examination with spectroscope B of some of these bright lines, as they appear under small dispersion, showed them to be really not single lines, but short groups of closely adjacent bright lines.

One of the brightest of these lines is found in the star No. 4013, at the position, according to Vogel, of λ 570.

Dr. Copeland's measure for this line is λ 568.9 in star 4013, and λ 570.4 in the star 3956.

As this position is not very far from that of the green pair of sodium lines at λ 5687 and λ 5681, it has been suggested that the line in the star is due to sodium, though there is no line of comparable brightness in the star's spectrum at the position of the dominant pair of the sodium spectrum at D.*

On confronting in spectroscope B the star line with the green sodium lines, the bright space in the star's spectrum was seen to consist of a short group of several bright lines close together and nearly equally bright. This group ap-

* The 570 line is most probably the green sodium line 569, the absence of the yellow sodium being explained by the half-and-half absorption and radiation mentioned in the discussion of the causes which mask and prevent the appearance of a line in a spectrum (Bakerian Lecture for 1888, 'Roy. Soc. Proc.,' vol. 44, p. 41).

peared to extend through about four times the interval of the sodium pair, which would make the length of the group about λ 0024. The green sodium lines cross the group at about one-fourth to one-third of the length of the group from its more refrangible end. The group in the star is rather less bright at the two ends, but there is no gradual shading off in either direction as in the case of a fluting.

When we examined this part of the spectrum with the small dispersion of a prism of 45°, we were pretty sure of a feeble bright line, less refrangible than the pair of bright groups in the yellow, and not far from the position of D. We were not able to see this line in spectroscope B with sufficient clearness to enable us to fix its position. It may be D, or, perhaps more probably D_3.

In No. 4001, Vogel saw a line at the position of the F line of hydrogen. It is probable that this line, as is the case in so many stars in which it appears bright, is variable, as we were not able to see it when the $H\beta$ line from a vacuum tube was thrown in. In the similar star D.M. + 37° 3821, as we have stated already, the F line of hydrogen was very bright.

We were unable to detect in any of the stars a brightening of the spectrum at the position of the chief line of the bright-line nebulæ. For this examination the lead line λ 5004.5 was thrown in, and the continuous spectrum of the star near to this position carefully scrutinised.

In their original paper, Wolf and Rayet state that they were not able to detect any nebulosity about the stars. They say: "Elles ne présentent non plus aucune trace de nébulosité" (*loc. cit.*, p. 292).

In a recent paper, Mr. Keeler, of the Lick observatory, confirms this view. He says: "At my request, Mr. Burnham and Mr. Barnard examined the Wolf-Rayet stars in Cygnus for traces of surrounding nebulosity, but with only negative result."

Notwithstanding these negative results, it appeared to us of great interest to ascertain further if any nebulosity would come out in a photograph of the stars taken with a long exposure.

Mr. Roberts responded at once to our wish when we asked his invaluable assistance, and on November 1st, of this year, he took a photograph of this region of Cygnus, with an exposure of two hours.

The three stars come out strongly upon the plate, but there is no nebulosity to be seen near any of them. There are faint stars in close proximity to the three stars, and apparently surrounding them, and, in the case of No. 3956, six of these faint stars are seen close to it, in an apparent spiral arrangement.

Though this surrounding of faint stars should be pointed out, it should, at the same time, be stated that the whole neighboring region is so densely studded with similar faint stars that it would be rash, perhaps, at present to suggest that this apparent connection of the bright-line stars with faint ones near them may be other than accidental.*

Professor E. C. Pickering informs me "that photographs have been obtained at the Harvard College Observatory of all the stars hitherto discovered whose spectra consist mainly of bright lines and are of the class discovered by Rayet. Part of these have been photographed at Cambridge, and the remainder in Peru." He states that they may be divided into three sub-classes, according to the characters of the bright lines. He says, further: "Photographs of the spectrum of fifteen planetary nebulæ have also been obtained. They resemble closely the spectra described above, except that the line 500 is strongly marked; 470 is seen in most of them, while the lines due to hydrogen are also bright."

It would seem that Professor Pickering's photographs do not permit him to distinguish the different positions of the bright blue band in some of these stars, for he gives for all the stars the same position, namely, λ 470.

‡ [Mr. Roberts has furnished us with the following description of the stars as they appear on his photograph:—

"No. 4001 appears as a multiple star made up of one bright, two fainter, and one very faint star partly behind the others; there is also a fourth bright star close to the multiple star. The group is surrounded by at least eight faint stars within a radial distance of ± 86″ of arc from center to center.

"No. 4013.—The photo-image of this star is made up of three stellar images touching each other in a line slightly curved. Two are bright and one faint; and there are indications of two other faint stars behind the two bright ones. This multiple image of four or five stars is surrounded by five bright and seven faint stars; all within a radial distance of 82″ of arc measured from center to center of the multiple star. The multiple image measures ± 55″ in length and ± 19″ in breadth.

"No 3956.—Its photo-image is ± 27″ in diameter. It is encircled by three stars of lesser brightness, and six faint ones within a radial distance of 59″, *i. e.*, there are nine stars within a radical distance of 59″."—Dec. 5.]

We regret that the insufficiency of our instrumental means has left our examination of the spectra of these stars less complete than we could wish. Our observations appear to us, however, to be conclusive on the main object of our enquiry, namely that the bright blue band in the three Wolf-Rayet stars in Cygnus, and in D.M. + 37° 3821, is not coincident with the blue band of the Bunsen flame.

THE EXCENTRICITIES OF THE ORBITS OF BINARY STARS.

T. J. J. SEE.

FOR THE MESSENGER.

For some time past I have been engaged on a rigorous mathematical investigation of the secular effects of tidal friction—especially as respects the excentricity of the orbit—in a system of two viscous or fluid bodies, both endowed with rotatory motion in the same sense as the orbital revolution. It is intended to be applicable to the systems of the binary stars, where both the primary and secondary stars are relatively of the same order of mass. Whilst the work is not yet entirely finished, it is sufficiently advanced that the chief results are already incontestibly established. Some of the conclusions are so very remarkable that I think they will interest astronomers. It is well known that the orbits of binary stars present every degree of excentricity from almost 0 to 0.9 (in the case of γ Virginis). A table of more than fifty of the best orbits hitherto determined, which I have collected from a great number of publications, presents to the eye, when the ellipses are drawn, orbits of every degree of elongation from that of one of the great planets, which is almost circular, to that of a comet such as Halley's. The arithmetic mean of the excentricities of these fifty orbits is almost 0.50. The same mean for the orbits of the great planets of the solar system is 0.044. That of the small planets is somewhat higher, whilst that of the satellites will closely conform to the small mean deduced from the orbits of the great planets.

The orbits of the small planets, however, can not be taken as typical of the solar system, any more than can those of

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comets or meteorites, on account of the great perturbations which the small planets suffer, and our inability to declare that the higher powers and products of the disturbing forces neglected in the planetary theory have not manifested themselves through a permanent secular increase in the excentricity of the orbits of bodies subjected during past ages to such great perturbations by the attraction of Jupiter and Saturn. The orbits of the great planets and of their satellites are therefore the only ones which can justly be taken as typical of the solar system. The average excentricity of these orbits is less than *one-tenth* of that of the fifty binary orbits. These latter very remarkable excentricities led me to suspect the operation of a physical cause (not distinctly impressed upon the orbits of the planets), whose continuous action had brought the star systems to their present configurations. The investigation proceeds upon a plan analogous to that adopted by Professor G. H. Darwin in his excellent researches on the history of the moon and planets of our system. Space does not allow me to detail the long and laborious mathematical investigation at hand, but the great importance of tidal action in a system such as γ Virginis may readily be conceived when we remember that the components are equal in magnitude, and therefore, perhaps, nearly equal in mass, each probably being of the same order of absolute mass as our sun. In a system composed of two such tremendous bodies of a gaseous or fluid nature, at any reasonable—say, planetary—absolute distance apart, the tides raised by mutual attraction would be simply enormous.

The relatively large mass of the secondary body in the binary systems contrasts strongly with the small, almost insignificant, mass of the planets in the system of the sun, in two respects:

(1) The great excentricity of their orbits, and

(2) The large relative mass ratio of their components (inferred chiefly from their relative magnitude) the binary systems are certainly radically and essentially different from our own. Now, the investigation shows that if we suppose the stars of a system, such as γ Virginis, originally to have been started close together in an almost circular orbit, they would have been wound off in the course of cosmic ages to a

great mean distance by the contiuous action of tidal friction; and meantime the excentricity of the orbit would have become extremely great, rising to a maximum at the maximum mean distance, where synchronism obtained, the momenta of rotation having been transferred into momentum of orbital motion, the parts of the exhausted system moving round slowly as though rigidly connected. The results of the investigation are so conclusive that I do not hesitate in the belief, not only that they establish the true origin of the remarkable excentricities of binary orbits, but also that the cosmical effects of tidal friction on the history of the heavenly bodies (except in the solar system) have been hitherto greatly underestimated.

The investigation seems to put it beyond all doubt that tidal friction is a sufficient cause to explain the great excentricities observed; and I hope eventually to show also that it is the *only possible* assignable adequate natural cause. It can easily be shown that binary systems are not products of the fortuitous approximations of separate stars; and hence it is necessary to suppose them genuine *ab initio*, and therefore to consider them products of some process of nebular evolution. This remark suggests interesting reflections on the process of formation and history of the binary systems; but this will be reserved for the present, and I merely remark that, for the reasons given above, and others, the mode of genesis appears to me to have been radically different from that embodied in the conception of Laplace as applied to the genesis of the solar system. This latter seems to be an exception and not the rule. Any hope of valuable results in cosmical investigations must rest upon a careful combination of the results of observation with those of rigorous analysis. Finally, I beg to add that the investigation on which I am engaged will be published in due time. Meanwhile I must beg the indulgence of astronomers in announcing results before the original work is available; the conclusions seemed to me to add an unusual interest to the astronomy of double stars.

BERLIN, PRUSSIA, Dec. 9th, 1890.

HOW TO MAKE A LENS.

GEORGE S. JONES.

FOR THE MESSENGER.

[The article on grinding and polishing a telescope mirror, published in the October number of THE MESSENGER, appears to have awakened some interest among amateurs, and a number of inquiries have been addressed to the editor for more particular information as to certain details of the work, the cost of materials, etc. The writer has consented to prepare a second article, in which is given a complete and detailed account of the process of making a small lens, which may be considered the A B C of mirror-making.—THE EDITOR.]

The outfit required by the amateur lens maker consists of a small lathe and accessory tools, a small supply of emery and jeweler's rouge, a few scraps of sheet brass, a supply of colorless glass (if optical glass cannot readily be obtained good plate glass, as free as possible from striated texture, will answer the purpose), and, in addition, some skill in working in metal.

THE EMERY AND ROUGE.

Procure half a pound of the flour of emery. Mix with water and knead well, to insure thorough wetting; put into a quart bottle, and fill the bottle with water, to which a little mucilage has been added; shake the mixture well and allow it to settle. The larger particles of the emery will fall to the bottom at once; the finest will remain in suspension for several hours. At the end of an hour draw off carefully with a siphon a portion of the still turbid water into a glass tumbler, and let it stand to settle for an hour or more. Pour the water from the tumbler back into the bottle. At the bottom of the tumbler will be found a deposit of fine emery—the finest, probably, that will be needed—which may be kept for use in a small vial filled with water.

The process of "elutriation" hardly need be described further. It will readily be seen that this process enables us to separate the flour, as it comes from the shop, into grades of different degrees of fineness. At least a half dozen grades should be prepared, the coarsest being obtained by allowing

no more than one minute, or even less, for the first settling. The residue left in the bottle, after the finer particles have all been removed, will come into use; but a small supply of emery of a still coarser grade will be needed for the rough grinding.

The rouge, which is usually sold in balls, had best be kneaded with water and kept for use in a small, wide-mouthed bottle. This bottle, as well as those which contain the fine emery, should be kept filled with water, to prevent the material from caking, and before use they should be shaken up well and allowed to settle when the superfluous water can be poured off.

THE GRINDING CUPS.

The materials for grinding and polishing being ready, we will make our first essay with a plano-convex lens of, say, one inch in diameter and two inches focal length. A piece of thin plate glass will answer for our first trial, and will offer the advantage of having one face already polished.

We cut a disk of paper, one inch in diameter, and paste it to the glass to serve as a mark in cutting the glass. Having cut this as close to the paper as possible, with a diamond or by other means—this work can be performed with a small pair of nippers, skillfully used—finish shaping the glass disk upon a grindstone or an emery wheel.

Turn a spindle of wood two or three inches long and of the size of a lead pencil, terminating in a flat head, to which attach the glass by means of sealing wax, thus providing it with a handle.

A grinding-cup may be made of a piece of thick sheet-brass. The diameter of this cup should be about the same as that of the lens, and the radius of its curvature should be one-half of the focal length desired. It may be hammered into shape roughly; then soldered to a spindle (which will serve as a handle) and turned carefully to the required concavity in the lathe.

In turning the cup a gauge will be needed, which, if we are not too particular about the focal length of our lens, may be made the most readily of stiff writing paper, by means of a pair of compasses, to one leg of which a cutter is attached. If we wish for greater nicety the gauge may be made of thin

sheet metal, thus: Set the compasses to the exact required length of the radius of curvature, and mark upon two separate plates of the metal two arcs of circles. One is to serve as a convex, the other as a concave gauge. Shape them as accurately as possible with a file, and then grind them together with fine emery and water or oil, until they fit each other perfectly. One of these gauges can be used for the cup, the other for the lens.

The rough grinding may be done in the lathe. Attach the brass cup to the chuck of the lathe and adjust it to run true. Hold the glass disk, wet and smeared with coarse emery, against the cup, by means of its spindle, in such a manner that one of its edges overlaps that of the cup. To do this the spindle must be held obliquely to the axis of the lathe. While the lathe is run in one direction, slowly, turn the glass regularly in the opposite direction, and continually vary the amount of the lap.

The cup will be ground as well as the glass, although less rapidly, and it will perhaps be well to rough-grind the glass in a special cup, which need not be shaped so carefully.

After the lens has been ground into shape, and, as tested by the concave gauge, is found to have the desired curvature, remove the cup from the lathe and finish the work by hand. Use in grinding both a twirling motion and straight, transverse strokes, and turn both lens and cup after each stroke, so that the grinding surfaces shall continually change their relation to each other. Hand-work, carefully done, is much superior to work done in the lathe. Before passing from one grade of emery to the next finer, examine the work with a glass, to be sure that all of the comparatively deep nicks are ground out. The last grinding should leave the surface of the lens of a milky whiteness with no marks upon it visible without a glass.

A polishing cup may be made of wood. Its diameter should be about one-tenth larger than that of the lens. The wooden cup should be lined with pitch, which is very conveniently prepared by melting rosin and adding a little spirits of turpentine. The hardness of the pitch should be such that, at the temperature of the room, it can be dented, not too easily, with the finger-nail. The cup should be fitted to the lens, which has previously been wet, while

the pitch is still soft, or it should be warmed for the purpose. The polishing can be done in the lathe, but better work can be done by hand. The same strokes should be used as in grinding—a combination of a twirling and a rectilinear motion. If it is found that the border of the lens is polishing faster than the center, make the cup smaller, or increase the length of the stroke. If the center polishes too fast, this indicates that the polisher is too small. At this point experience, born of practice, must take up and continue the instruction.

To grind the edge of the lens, after it has been polished, insert it, still attached to its spindle, into the lathe, so that it runs true. Bend a strip of thin metal, an inch or so wide and two inches long, partially around the edge of the lens on the under side, and allow the lens to turn in it while it is kept liberally supplied with emery and water. In this way the edge of the lens may be ground perfectly true, and it may be cut down to any desired size.

If it is desired to make a lens of any other form than plano convex, the following formula will be found convenient for determining the length of the radii of the two faces:

$$F = \frac{2rr'}{r' - r}$$

when both faces curve in the same direction, as in the meniscus; and,

$$F = \frac{2rr'}{r' + r}$$

when they curve in opposite directions, as in the double-convex.

In this formula F is the principal focus; r and r', the radii of the two faces.

It is assumed in this formula that the index of refraction of glass is $\frac{3}{2}$, which is a little under its true value, and the focal length of the lens will, therefore, turn out a trifle less than calculated. If extreme accuracy is desired, the formula to use is:

$$F = \frac{rr'}{(n-1)\,(r' \pm r)}$$

in which n is the index of refraction of the glass used.

NOTE ON THE DOUBLE STAR Σ 186.

S W BURNHAM.*

For The Messenger.

There has been a decided change in both the angle and distance of this pair since it was discovered by Struve. It was then an easy object with almost any instrument, but the distance slowly diminished until it was noted by many observers as single, or with an uncertain elongation. It is still a close pair, but readily within the reach of the large refractors with which it has been observed during the last few years. No orbit has yet been computed, although nearly half a revolution has been described since the first measures of Struve. Many of the measures have large errors, and probably only a very rough approximation to the period could be made from the data now available. Careful measures during the next few years are very important for this purpose. The relations of the two components are fairly well shown since 1874, but the measures between that time and 1831 are unusually discordant for a pair of this kind, as it is evident that it could not have been single at any time since its discovery, except perhaps apparently so with small instruments.

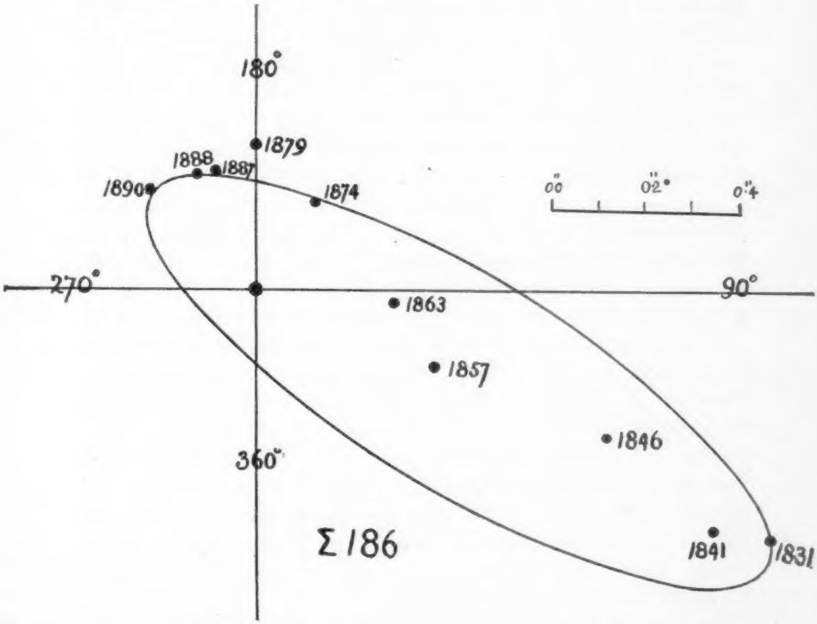
I have selected a few measures by the best observers and accurately platted them to scale on the accompanying diagram. These observations are as follows:

1831.12	64°.7	1″.23	Σ	3n.
41.70	241 .8	1 .11	*O*Σ	1n.
46.11	68 .2	0 .82	*O*Σ	1n.
57.92	67 .5	0 .42	Se	3n.
63.85	85 .1	0 .3	Da	1n.
74.90	145 .7	0 .23	N	1n.
79.89	180 .5	0 .31	Hl	3n.
87.02	199 .1	0 .27	Sp	2n.
88.05	206 .3	0 .28	Sp	3n.
90.88	227 .1	0 .31	β	3n.

The ellipse shown is the result of an attempt to find a curve which would fairly represent the more recent measures and the first observations of Struve. It is evident that the intermediate measures cannot be reconciled, without large

* Lick Observatory, Mt. Hamilton, Cal.

corrections, with any curve passing through the points referred to. If we disregard the last three measures, the path of the companion would be as well represented by a straight line as by any curve, but the later observations taken in connection with Newcomb's observation in 1874, make it quite certain that the relative change is not one of proper motion. According to Struve the meridian observations of the princi-



pal star, or rather of the two components considered as one star, for it must have appeared single with the meridian circle, show a proper motion of about a quarter of a second per annum, and this is evidently common to both components. Perhaps a flatter or more elongated ellipse could be used, but the plane of the orbit must form a considerable angle with the line of sight.

The last measures of this pair were made with the large equatorial, and should be fairly accurate as a double star of this distance is very easy with an aperture of 36 inches under ordinary conditions.

PHENOMENA OBSERVED UPON SATURN AT THE TIME OF THE PASSAGE OF THE SUN AND OF THE EARTH THROUGH THE PLANE OF ITS RINGS, IN 1877-1878.*

E. L. TROUEVLOT.

In a paper "On the Variation of the Rings of Saturn," published in the *Bulletin Astronomique*, I said a few words about the interesting phenomena which I observed in 1877 and 1878, before, during and after the passage of the sun and of the earth through the plane of its rings. Since conditions nearly identical with those to which the observed phenomena might be attributed are about to present themselves again in 1891 and 1892, toward the time of the passage of the earth and the sun through the plane of these same rings, and since we are permitted to suppose that similar causes will produce phenomena of the same kind, I believe this to be an opportune time to make known these phenomena, in the hope that by calling attention to them, observers, having a complete knowledge of their cause, will be able to prepare for observing them under the most favorable conditions, and for verifying them if they have opportunity. Toward the middle of May, 1877, a series of observations was undertaken with a view to studying and following, day by day, as circumstances would permit, the phenomena, as yet little known, which result from the progressive approach and retreat of the sun and of the earth to and from the plane of the rings of Saturn, as well as those which result from the successive passage of these two bodies through the same plane.

The conditions required for the observations of these phenomena should for a little while, be found united. In fact, the sun and the earth, both of them then being north of the plane of the rings, gradually lowered toward this plane which they crossed; the first toward the 6th of February, and the second about the 1st of March, 1878; then receded gradually and occupied on the south the positions successively identical with those which they had each occupied on the north before their passage.

This program was only partly realized, for after the passage of the earth through the plane of the rings, my health

* Translated from the French by Miss Isabel Watson, teacher of French, Carleton College, Northfield, Minn.

prevented the continuation of these observations, which, with the exception of that of May 27th, 1878, were not resumed and followed regularly until the 27th of the following September, and from that time to the 10th of February, 1879. Thanks to the state of the heavens, which were exceptionally favorable for astronomical observations during that period, Saturn was observed 221 times under excellent conditions; 139 times before and 82 times after the passage of the earth through the plane of the rings, and at the same time numerous drawings of the planet and of the principal phenomena observed were obtained. The observations were made by the aid of an excellent telescope by Merz, of $0^{m}.16$ aperture, and according to the state of the atmosphere and the phenomena to be observed, magnifying powers varying from 85 to 460 were employed.

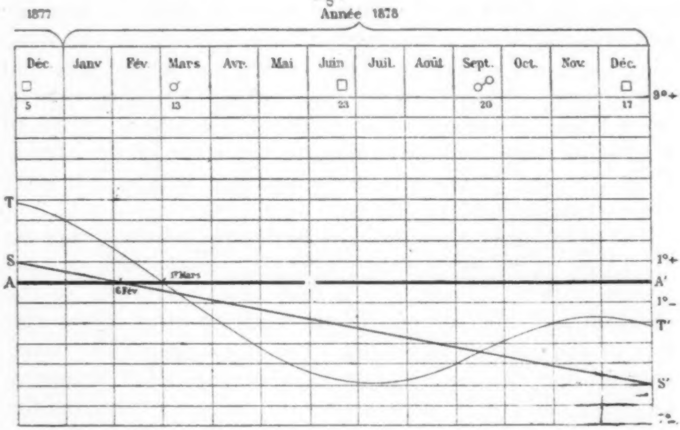
The phenomena observed may be divided into two classes: (I) Those which concern the rings; (II) those which pertain to the sphere. Those of the first class relate (1) to the decrease and the increase of the brilliant light of the surface of the rings; (2) to the invasion of their illuminated surface by a shadow; (3) under a strong solar obliquity Cassini's division is more visible on one ansa than on the other; (4) the anterior part of the ring appears narrower than the posterior; (5) the disappearance of the rings.

Those of the second class relate, (1) to the deformation of the limb of Saturn; (2) to the inequality of the light between the central portions of the globe and those which form the edge.

To understand easily the phenomena which we have to explain, it is necessary that the reader should have an idea, at least approximate, of the position occupied by the sun and by the earth, whether to the north or to the south of the plane of the rings at the moment when these phenomena were observed. The diagram (Fig. 1) of which the ordinates represent the different months of the year, and the abscissæ the elevation of the sun and of the earth either to the north or to the south of the plane of the rings, will permit the reader to see at a glance the approximate positions occupied by the two heavenly bodies at any date whatever comprised within the period of the observations. The horizontal line AA′ represents the plane of the rings; the oblique

line SS′ gives the apparent path of the sun, and the undulating line TT′ gives that of the earth. The arrows indicate the direction of the movement of the two bodies. The symbols ☌, ☍, □, mark the conjunctions, the oppositions and the quadratures of Saturn with the sun; and the figures which accompany them give the date of the phenomenon.

Fig. 1



I. *The Decrease and the Increase of the Brightness of the Illuminated Surface of the Rings.*

From the first days of my regular observations of Saturn, May 18, 1877, I remarked with surprise that, contrary to what I had always seen up to that time, the illuminated surface of the ring seemed decidedly less luminous than the planet. Subsequent observations only confirmed the first, and it was certain that its relative brightness had diminished since my observations of 1872–1876. Not only was it certain that its brightness had diminished, but it soon became evident that it was growing less and less from day to day.

All observations confirm this phenomenon and show in the most evident manner that the light reflected from the surface of the rings diminished gradually until the day of the passage of the sun through their plane. Not only had the brightness been gradually diminishing during this period of nine

months, but also the color of the light changed, and, compared with that of the planet, it appeared yellowish and even slightly orange. While the results of my observations of 1872-76 were exactly opposite, that is to say, during that period the color of the planet compared with that of the rings appeared yellowish, while that of the rings themselves was white.

Although the observations of the same phenomenon, after the passage of the earth and the sun through the plane of the rings were much less numerous than those which were made before these passages, still there is no doubt that the phenomenon existed then as before. Indeed, it has been proved several times, and notably the 28th of August, 1878, that "the ring appeared less luminous than the ball and that its color was yellowish." At this last date it was just this yellowish tint of the ring which enabled one to distinguish it on the planet which was comparatively white. Nevertheless the phenomenon was approaching its end, for a month later, Nov. 26, it was ascertained that "the ring appeared almost as bright as the ball," and a few days later, Dec. 6, "one could easily see that the ring was brighter than the planet." From that day until this, the ring of Saturn has constantly held a brightness superior to that of the globe, just as it did before 1877. If one seeks the propable causes of this decrease and increase in the brightness of the ring, one is led to think that they are due either to the position of the earth or to that of the sun with relation to the plane of the rings. If it is to the position of our globe that this phenomenon should be attributed, we ought to be able to assure ourselves of it by the increase and decrease of its brightness corresponding to the periodical retreat and approach of the earth to the surface of the rings. Now, observations have never shown anything of the kind. From May 18, 1877, to Feb. 6, 1878, and from this last date until Oct. 28, of the same year, the brightness of the surface north of the ring was gradually decreasing in the first period, and that of the southern surface was gradually increasing during the second. Then one must admit that the position of the earth counted for nothing, or in any case for very little, in the production of the phenomenon. It is then in the position of the sun that we

must seek the cause. We have already shown that the sun approached the plane of the rings until the day of its passage through this plane, and that afterward it receded with the same regularity. Now these phenomena of decrease and increase in the brightness of the light observed on the opposite surfaces of the ring are in perfect conformity with the successive positions of the sun, whose decrease in height corresponds exactly to the diminution of the light on the north surface of the ring and whose increase in height corresponds to the increased brightness of the southern surface. It is then necessary to admit that the phenomenon was due in great part, if not altogether, to the position of the sun with relation to the plane of the rings.

If, accepting these facts we assume, as indeed our observations from May 18, 1877, to Dec. 6, 1878, seem to authorize us to do, that the same things take place on the northern surface of the rings as on the southern, it will be easy for us to deduce approximately the date of the year 1877 when the ring began to diminish in brightness, as well as that when its brightness was equal to that of the planet. Indeed if a brightness always approximately equal corresponds to a given height of the sun above the plane of the ring, it follows that if we are able to find what the dates were in 1877 when the height of the sun equalled $+ 4° 30'$ and $+ 4° 23'$, we have solved the problem.

We find that the first height corresponds to April 6, and the second to April 16, 1877, that is to say, that it was about one month before we had begun our observations that the northern surface of the ring had commenced to undergo a decrease in brightness; so that on April 16 the diminution was such that the ring and the planet were equally bright.

According to these observations and the deductions that we have drawn from them, it would seem that when the height of the sun is reduced to $4° 30'$, the surface of the ring gradually diminishes in brightness in proportion as that body lowered toward the plane of the ring, and that, after having crossed this plane, the opposite surface gradually increases in brightness in proportion as the sun goes higher, until the day when it reaches a height of $4° 30'$. But how can the position of the sun affect the luminous intensity of

the ring? Is this weakening a unique occurrence, and does it conform to the law of Lambert, who claims that the quantity of reflected rays diminishes in proportion as the angle of incidence increases? Or is it rather due to other causes, such as the absorption of solar rays by an atmosphere belonging to the rings, etc., etc.? At present we have no data for replying to these questions; but we may be permitted to hope that the observations made at the time of the approaching passages of the sun and of the earth through the plane of the rings will enable us to answer them.

II. *The Gradual Invasion of the Illuminated Part of the the Ring by a Shadow.*

From Oct. 6, 1877, when the sun was 1°49′ to the north of the plane of the ring, until Feb. 6, 1878, the day of its crossing the same plane, the illuminated surface of the ring kept gradually decreasing in size, in proportion as the height of the sun decreased, so that Feb. 5, the evening before the passage, the bright surface was no longer shown except by a narrow luminous thread, very difficult to recognise because of its extreme thinness (Fig. 2).

The phenomenon consisted in a gradual invasion of the anterior surface of the ring by something which resembled a shadow cast by an opaque body, and which, little by little, advanced upon it and obscured it.

The 6th of October the phenomenon was already rendered apparent by a pronounced eclipse of the part of the ring which crossed the planet. December 18, when the height of the sun was reduced to + 0°44′, the phenomenon was much more accentuated, and all the part of the ring which crossed the ball, as well as the parts near the ansæ were obscured. Jan. 25, 1878, when the elevation of the sun was not more than 0° 12′, the encroaching shadow stretched so far upon the ring that it reached even to the posterior part, and seemed to mingle with that which the ball then cast upon it to the east (Fig. 3) in such a way that the eastern ansa seemed entirely separated from the planet by a dark gap, which in size and position corresponded with the shadow cast by Saturn upon its rings. Besides, the angular shape of this shadow, very easy to recognise, left no doubt about its identity. February 4, when the sun was not more than

+ 0° 5′ high, the lighted surface formed only a luminous streak sharply defined and of extreme thinness (Fig. 2), which the 5th of February, the evening before the passage of the sun through the plane of the rings, was very difficult to distinguish, and seemed, at moments, discontinuous and formed of luminous globules hardly perceptible.

Evidently the phenomena in question could not be explained by the increasing obliquity of the surface of the ring, caused by the progressive lowering of the earth towards its plane; in the first place, because the gradual decrease of the illuminated part of the ring was not at all in proportion to

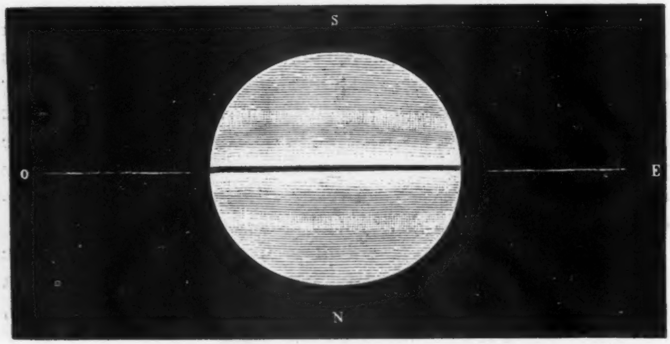


Fig. 2.

the lowering of our globe, but took place more rapidly; and also, because this illuminated surface, instead of being a perfect ellipse, had an irregular form (Fig. 3). And then, the elevation of the earth, which the 6th of October was +3°21′ and kept increasing until Nov. 16 when it was +3° 55′, was still + 1° 20′ the 5th of Ferbuary, 1878, when the illuminated portion of the ring was reduced to an interrupted luminous streak, and so narrow that it was difficult to distinguish it. Now when the earth occupies an identical position, or even one inferior to that which it held at the last date, the ring is still a very remarkable object, subtending an angle of 0″.86, and upon which one still distinguishes easily the opening of the ansæ, and which cannot pass unnoticed even with instruments of small aperture, while at

the same time the height of the sun is scarcely less than 2° (Fig. 4), which is the projection of Saturn and its rings for Feb. 4, 1878, shows the ring as it must have appeared if its surface had been flat and consequently exposed to the rays of the sun.

Neither can the phenomenon be attributed to an error of observation, when the shadow cast by the ring upon the ball would have been taken for and confused with it. In fact, the 6th of October this shadow cast toward the north already began to disengage itself from the nebulous ring C, from which it was separated by a narrow thread of light be-

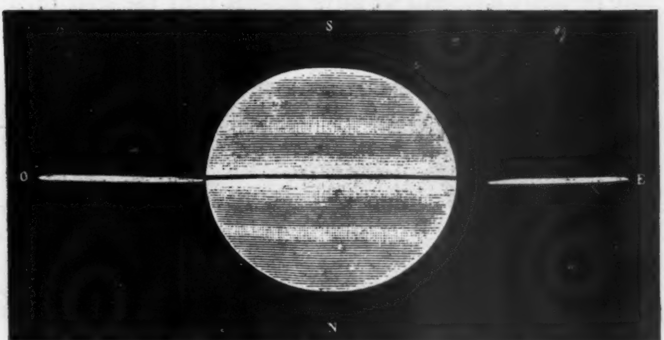


Fig. 3.

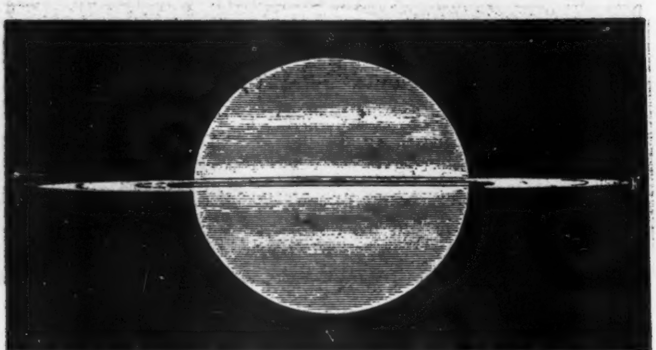
longing to the globe. This thread of light separating the shadow from the ring C increased from day to day in the same measure that the shadow thus cast decreased; so that, if by an error, the thread of light belonging to the globe had been confounded with the ring, the illuminated surface of the latter ought to have grown larger instead of smaller, as the observation showed it. Besides the darkening of the ring stretched out beyond the globe, which amply suffices to show that it was distinct from the shadow cast by the ring since that could not reach beyond the globe.

The close connection observed between the increase of the shadow on the illuminated surface of the ring and the lowering of the sun on its horizon shows clearly that that body was the principal cause of the phenomenon.

In reflecting upon the causes which would be capable of producing such a darkening on the ring, we hardly find more than one which can explain it and even that one offers some serious difficulties. We attribute the observed phenomenon to the elevation above the general level of a zone slightly inclined toward the planet. Supposing that the rings had a flat surface, it is evident that this surface would receive the solar rays and consequently would remain visible as long as the sun remained above it.

We have shown elsewhere (*Bulletin Astronomique*, t. II, p. 16 and following, 1885) that the form of the shadow of the ball cast on the rings could not be reconciled with a surface perfectly flat, and we have shown that the level of this

Fig. 4.



surface is changeable and varies often in height. From the form of the edges of this shadow we have decided that the maximum thickness of these rings is found on the ring B, at some distance from the division of Cassini. Now if, inside of this division, the ring B possesses a variable zone of a considerable height, it will result that, when the sun approaches the plane of the ring, this more elevated zone, intercepting the solar rays, will cast a shadow behind, which will extend farthe and farther in proportion as the sun descends, and which will end by covering almost all the part within this zone and nearly the half of the surface of the ring A, the half most distant from the sun.—*Bulletin Astronomique.*

[To be Continued.]

A BRIEF BIBLIOGRAPHY OF ASTRONOMICAL LITERATURE FOR THE YEAR 1890, JANUARY TO JUNE.

COMPILED BY WILLIAM C. WINLOCK.

The following brief subject-index of astronomical literature is intended to form a continuation of the bibliography of astronomy that has been published in connection with the Smithsonian review of Astronomy since 1885. The year 1890 is divided into two parts, but is it expected that the bibliography for 1891 will be continued as a quarterly appendix to THE SIDEREAL MESSENGER.

To make a work of this sort exhaustive, even to the extent of including all the material that comes under the compiler's notice, would expand our index to undue proportions, and seems for the present to be out of the question. As some selection has been imperative, an effort has been made to meet what are conceived to be the general wants of the astronomer, assuming that the special papers that interest but few readers will come to the notice of the latter without difficulty. Any suggestions upon this point will be welcomed by the compiler, who will also be glad to receive the titles of any papers that it would seem desirable, for any reason, to include. It should be added that through the courtesy of the officers in charge, access is had to the library of the U. S. Naval Observatory, and to that of the Smithsonian Institution, which together probably furnish the most complete collection of current astronomical literature in this country.

Journal articles are included in the index, as well as more formal and elaborate publications—a few titles being taken from reviews or book catalogues.

The arrangement is by subjects, with a sub-arrangement by authors or catch-words. The abbreviated titles of Transactions or Journals follow in the main the principles laid down by Dr. Billings and Dr. Fletcher in their great subject-index catalogue of the Surgeon General's Library U. S. Army, in Washington. Of the less obvious contractions the following will probably be an adequate explanation:

abstr.	abstract.	k. k.	kaiserlich, koniglich.	p.	page.
Am.	American.	lfg.	lieferung.	pl.	plates.
bd.	band.	n. d.	no date.	portr.	portrait.
d.	die, der, del, etc.	n. p.	no place (of publication.)	pt.	part.
ed.	edition.	n. f.	neue Folge.	r.	reale.
hft.	heft.	n. s.	new series.	rev.	review.
hrsg.	herausgegeben.	not.	notices.	s.	series.
il.	illustrated.	obsry.	observatory.	sc.	science, scientific.
j., jour.	journal.			sup.	supplement.
				v., vol.	volume.

In the references to journal articles the volume and page are simply separated by a colon; thus:

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signifies, Astronomische Nachrichten, volume 123, pages (or columns) 275 to 282, published in 1890.

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PENDING PROBLEMS IN SPECTROSCOPY.

GEORGE E. HALE.

FOR THE MESSENGER.

The great activity of scientific research at the present time cannot be regarded without astonishment. Thousands of investigators in all parts of the world are daily bringing to light new facts of the greatest interest and value. And especially is this true in the almost unexplored domain of spectroscopic astronomy. Here the physicist and astronomer meet on common ground, and their combined resources make clear the path of progress. It is impossible in a single paper even to mention all the objects of their search, but a few of the more important may be briefly reviewed.

Even those most opposed to the views set forth by Professor Lockyer in his "Meteoritic Hypothesis," will admit their value in stimulating enquiry, and already many uncertain points have been cleared up. Professors Liveing and Dewar have repeated and extended their studies of the magnesium spectrum,* proving almost conclusively that oxygen is neces-

* Proc. Royal Society, vol. 44, p. 242.

sary to the production of the green fluting, and showing that a temperature much higher than that of the Bunsen burner is involved in its formation. At the same time they were not able to obtain the fluting in the presence of hydrogen, and were inclined to believe that the b group is more characteristic of magnesium at a low temperature. When it is remembered that hydrogen is clearly present in the nebulæ with no trace of the b lines, it is hard to accept all of Professor Lockyer's views of these bodies,* though at the same time it would not be wise to reject them entirely. The question as to the presence of the magnesia fluting in the nebula spectrum is not yet decisively answered, but the indications point to its absence.† The difficulties in direct comparison arise from the uncertain relative motions of the nebulæ and the sun, but in the case of the Orion nebula these do not enter to any appreciable extent. The character of the nebula line seems to most observers to preclude its identification with the magnesia fluting, but others take the opposite stand.‡ It may be said that there is still room for work on this important subject, but observations will be worthless unless conducted with the greatest care, and with a knowledge of their degree of accuracy.

Mr. Keeler's discovery of motions of the nebulæ in the line of sight is an important indication of spectroscopic progress as it signalizes the advent of high dispersion with its attendant advantages.§ The fact that there is a motion is not so much to be wondered at as the possibility of measuring it, for, as Mr. Keeler remarks, it would be more surprising to find the nebulæ at rest than in motion. The small probable error of these measures is especially to be noticed, and in the observations of α Bootis the comparison of Keeler's results with those obtained photographically by Vogel,‖ show plainly that the era is past when the motion of a star could only be certainly expressed as positive or negative. It is probable that the anomalies in the motion of Sirius will soon disappear under the new order of things.

Double stars have only recently become special objects of

* Meteoritic Hypothesis.
† Sidereal Messenger, August, 1890; Pub. A. S. P., No. 11; Meteoritic Hypothesis, p. 297.
‡ Sidereal Messenger, January, 1891, p. 23.
§ Pub. A. S. P., No. 11, p. 265. ‖ *Ibid*, p. 284.

spectroscopic study, but now it is known that the prism can multiply about five thousand times the power of the object glass in separating close and rapidly revolving pairs.* By the periodic doubling of the K line in the spectrum of Mizar Professor Pickering has discovered a system of suns with a period of only 104 days, and a combined mass forty times that of our central luminary. β Aurigæ offers an even more remarkable example, for in this case the complete revolution is performed in only four days. Similar cases may at any time be picked up on the Harvard Observatory plates, for the northern skies are being explored at Cambridge, while a party sent out from the same Observatory to South America is working in the less familiar regions of the heavens. The studies of the stellar spectra which constitute the Draper Memorial are the most exhaustive ever undertaken, and the almost daily discoveries of stars with peculiar spectra are only the natural results of such diligent search.

The latest addition to the growing list of "spectroscopic binaries" comes from Professor Lockyer's Observatory at South Kensington, where Fraunhofer's method of using a prism over the object glass, so advantageously employed by Professor Pickering, has been adopted. Photographs of the spectrum of α Lyræ show a periodic doubling of the lines, the maximum separation corresponding to a velocity of 370 miles per second in the line of sight.† A period of 24.68 hours was deduced by Mr. Fowler, but this is considered by Professor Pickering as too short to allow the binary nature of the star to escape detection in the large number of photographs made at the Harvard Observatory.‡ He believes that the doubling of the lines can be accounted for on the supposition of a very elliptical orbit, in which case the duplicity would be apparent only for a few hours at periastron at the time of most rapid motion. Or, possibly, the presence of a third disturbing body may cause irregularities, as is the case in η Ursæ Majoris. The appearance of the lines in photographs taken at predicted times of doubling will be awaited with interest.

It has been supposed for over a century that the varia-

* Pickering's Fourth Annual Report Draper Memorial, 1890, p. 7.
† Proc. R. S., November, 1890.
‡ Sidereal Messenger, January, 1891.

tions in the light of Algol were caused by the interposition of a dark satellite, but positive proof was lacking until the spectroscopic results of Vogel in 1888 supplied the requisite evidence.* In its motion about the center of gravity of the two bodies Algol alternately moves toward and from the earth, and consequently the lines in its spectrum are displaced first toward the blue and then toward the red. A careful series of measures of the photographic plates gave an orbital velocity of 26.3 miles per second for Algol, and its orbit is consequently some two million miles in diameter. Assuming the same mean density for both primary and satellite the photometric determination of the loss of light in eclipses gives a rough means of deducing the relative masses, and the system has thus come to be fairly well known. Algol has a diameter of about a million miles, while the satellite is somewhat smaller than our sun. Their distance of only a little more than three million miles from center to center is certainly not compatible with much eccentricity in their orbits. Only a few months ago α Virginis was found by Vogel to be the principle member of a similar system the period being about 4 days, and the maximum motion in the line of sight about 56.6 miles.†

In the study of stellar spectra apart from the question of motion in the line of sight, progress is almost equally rapid. It is unfortunate that the method employed at the Harvard Observatory precludes the use of comparison spectra; the interposition of absorption solutions etc., in the path of the rays has been wholly without success, largely from the diffuse nature of the lines thus obtained. As yet a slit is essential in determining the origin of any line, except perhaps in such well marked cases as the hydrogen series. Dr. Vogel has obtained photographs sharp enough to allow the identification of a large number of lines by Scheiner,‡ and Dr. Huggins has found the two lines necessary to complete the hydrogen series in Sirius, as well as a new group of six lines in the ultra-violet.§ Perhaps the most interesting spectroscopic information recently obtained by Dr. Huggins has been with regard to the photographic spectrum of the Great Nebula in Orion. The new photographs show many lines

* Astronomische Nachrichten, No. 2947. † *Ibid*, No. 2923.
‡ *Ibid*, No. 2923. § Sidereal Messenger, Aug. 1890, p. 318.

not found in the 1889 plates, and especially noticeable is the presence of h and H, as well as the first two lines of the hydrogen series. It is an important fact that these lines grow stronger and broader as the Trapezium is approached, and that the spectrum differs considerably in other particulars in different regions of the nebula.* A complete spectroscopic study of the nebula in sections is evidently very desirable.

The changes in the spectra of variable stars also need to be carefully studied, and Lockyer's theory of variability offers at least a basis of comparison.† The probable complimentary relations of the components of double stars as revealed by their spectra suggests unlimited possibilities in still another direction. And solar work is not to be neglected. Though the prominences have been observed for more than twenty years they still have many secrets to reveal. The spectra at different elevations above the limb; the unequal distortions of different lines of the same metal;‡ the identity of the lines widened in spots at various times in the eleven year period,§ as well as the lines reversed in spots; these are a few of the many subjects still open to investigation. We are, moreover, still ignorant of the true nature of "helium," and the presence of the D_3 line in many star spectra renders its indentification more desirable than ever. "Coronium" also, is still a mystery. But the extensive investigations now in progress in Professor Rowland's laboratories will soon displace the highly inaccurate wavelength determinations of Angstrom, Thalèn, and other physicists and furnish the standard measures of metallic lines demanded by the high dispersion now employed. It is stated that Professor Rowland has already added several elements to the list of those known to be present in the sun.

The importance of laboratory work becomes daily more apparent. The innumerable results of telescopic observation must be interpreted, and peculiar spectroscopic appearances, if possible, reproduced. Lockyer's experiments on the spectra of meteorites may profitably be repeated with higher dispersion,‖ and the variations of spectra at different temperatures offer a no less fruitful field of study.¶ Pro-

* Sidereal Messenger, August, 1890, p. 316.
† Meteoritic Hypothesis, p. 475. ‡ Chemistry of the Sun, p. 348.
§ Ibid, p. 310. ‖ Proc. Royal Society, vol. 43, p. 117.
¶ Chemistry of the Sun, p. 194. See also, Liveing and Dewar, Proc. Royal Society, vol. 44, p. 241.

fessors Liveing and Dewar are especially active in investigations of this nature, and their recent studies* of the spectroscopic properties of dust are very significant.* Crew, Dunér and Wilsing have detected a difference between the time of rotation of the sun as given by observations of the spots and measurements of wave-length changes at the limb. Numerical relations between the lines in the same and different spectra, first noticed by Mitscherlich and investigated by Lecoq de Boisbaudran, have been studied by a large number of physicists, and Ames' recent researches on the spectra of cadmium and zinc establish an undoubted connection of the greatest interest.† Examples might be multiplied, but enough has been said to indicate the enviable opportunities of the spectroscopist.

KENWOOD PHYSICAL OBSERVATORY,
Chicago, Jan. 19, 1891.

ASTRONOMY IN RECENT PUBLICATIONS.

The Astronomical Journal, Jan. 9, 1891, has for its leading article, "The Reduction of Astronomical Photographic Measures," by Harold Jacoby. The theme is presented by the aid of geometrical figures and mathematical formulæ. Then follow "Note on the Elements of γ Cygni," "On the Period of 2100 U Orionis," and "Observations of Variable Stars in 1890."

The Journal of the British Astronomical Association, No. 2 of Vol. I, is for November, 1890, and its contents contain a report of the meeting of the Association, on Nov. 26, 1890, paper communicated to the Association by A. W. Thompson on the determination of the heliographic latitude and longitude of sun spots; by A. M. W. Downing, on the eclipses of Jupiter's satellites; by S. J. Johnson, on British astronomical sights in ancient days, and by A. Stanley Williams, on recent observations of the canals and markings of Mars.

Knowledge (London). January number begins Volume XIV, and is handsomely and fully illustrated. The full page

* Sidereal Messenger, Jan. 1891, p. 9.
† Phil. Mag. [5] 50, (1890) p. 33.

plate, by the direct photo-engraving process, showing a group of sun-spots, taken at Meudon June 1, 1881, by Janssen, with an object glass of five French inches aperture, is a noble specimen of what can be done with a small telescope. It shows the structure of the photosphere of the sun well. Two such plates accompany an article by A. C. Ranyard, entitled "The Sun's Photosphere."

Observatory, January, 1891, gives reports of the meetings of the Royal Astronomical Society December 12, 1890; of the Astronomical Society of the Pacific, Nov. 20, 1890; of the Liverpool Astronomical Society on Dec. 1, 1890, and of the meeting of the Royal Astronomical Society, Dec. 17, 1890. The articles are, Bright-line stars of the Wolf-Rayet type, by Miss A. M. Clerke; the extension of the corona and the details of its structure, by F. H. Bigelow, Washington, D. C.; Motions of the nebulæ in line of sight, by J. E. Keeler of Lick Observatory; Comet Perihelia, by W. E. Plummer; the proper motion of Σ 547, by S. W. Burnham, of Lick Observatory.

Astronomische Nachrichten, No. 3010, has a timely article on provisional results of observations at Berlin, Potsdam, and Prague, concerning the variation of latitude by von Th. Albrecht. This number also contains a series of observations of Comet Spitaler by R. Spitaler himself at the Royal Observatory of Wien-Währing under date of Dec. 20, 1890. The ephemeris of Comet 1890 IV (Zona) for months of January, February and March is by A. Berberich.

Himmel und Erde for December contains a leading article on the theories of the aurora, with a fine full-page plate as frontispiece. Other papers are on the system of ζ Cancri, photography in meridian observations and a description of the Observatory at Nice, besides a number of brief articles.

Solar Prominences in December 1890.

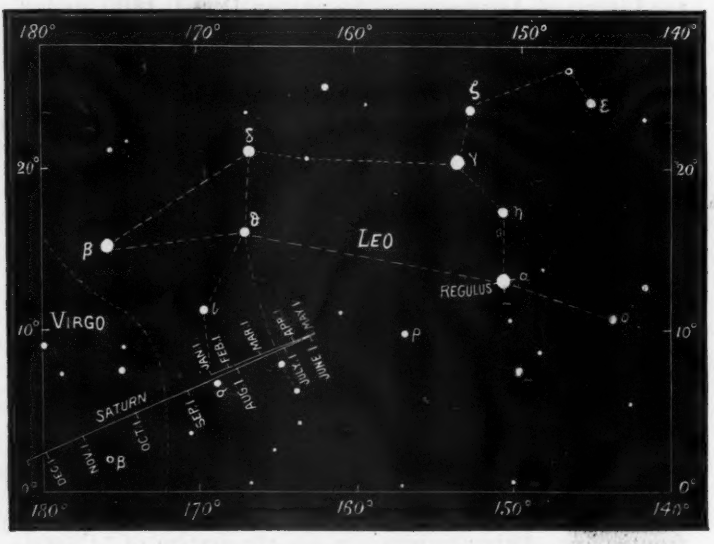
DATE.	POSITION ANGLE.
2	120, 242, 311.
4	284, 302, 348.
12	75, 122, 148, 230, 320.
19	80, 160, 227, 240.
20	45, 139, 226, 229.
22	45, 64, 150, 259, 274, 324.
28	117, 243, 295 to 305, 280, 288, 320.

Camden Observatory, January 1st, 1891. E. E. Reed, Jr.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury, for the first few days of February, will be visible to the naked eye in the morning an hour before sunrise. He will at that time be only a few degrees above the southeastern horizon. On the morning of Feb. 7 Mercury will be just above the moon. Mercury and Jupiter will be in conjunction on the morning of March 5, but both planets will then be too near the sun to be seen except during the day.



PATH OF SATURN AMONG THE STARS IN 1891.

Venus is also "morning star." All early risers have doubtless been struck with the brilliancy of this planet, seen toward the southeast in the morning, up to the time of sunrise and even later, far surpassing the brightness of any of the neighboring stars. During this month the brilliancy will decrease nearly one-third because of the increasing distance of the planet from us, while the phase will change from crescent to gibbous. On Feb. 13 the disk will be exactly half illuminated, the planet being then at greatest elongation west from the sun, 46° 51′. On the morning of Feb. 6, Venus, Mercury, and the crescent moon will form an interesting triangle, Venus being the highest and most westerly, moon and Mercury at almost equal altitudes, Mercury farthest to the east.

Mars has an apparent diameter now of only 5.6″, so that but little of detail can be be seen upon his surface. His distance from the earth is about 170,000,000 miles. He is moving eastward and northward among the inconspicuous stars of the constellation Pisces, and may be seen in the southwest from 6 to 9 P. M.

Jupiter will be in conjunction with the sun on the morning of Feb. 13.

Saturn is in splendid position for observation after midnight, and may be well observed in the evening. He will be at opposition to the sun March 4. The earth is now about 3° below the plane of Saturn's rings while the sun is a little over 4° below that plane. The angle of the earth below the plane of the rings will for a few months increase, but that of the sun will steadily decrease until Oct. 30, when the sun will pass through the plane of the rings. It is important that observers begin at once to closely watch the changes in the rings so as to verify or throw some light upon the phenomena observed by Trouvelot in 1878 (see article p. 74). We give this month Mr. Marth's ephemerides of the satellites for the benefit of those who wish to study the phenomena of the satellites. We give also a diagram of the path of Saturn among the stars of Leo and Virgo during the year 1891, which we hope will be of use to students of astronomy.

Uranus may be observed after midnight. He is in the foot of Virgo about 10° east of Spica and 2.5° south-west of κ Virginis. He will be stationary in right ascension Feb. 4, and after that date will have a retrograde motion. He will be in conjunction with the moon, south 2° 49′, Feb. 28 at 4 A. M. central time.

Neptune may be observed in the evening. He is still in the same field of view with the two eighth-magnitude stars, west of ε Tauri, mentioned last month. The planet is about a half-magnitude fainter than the stars and has more of blue color in its light.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Feb. 23........	21 07.2	− 18 13	6 06 A. M.	10 54.0 A. M.	3 42 P. M.
Mar. 5........	22 09.7	− 13 40	6 09 "	11 17.0 "	4 25 "
15........	23 15.7	− 6 57	6 08 "	11 43.5 "	5 19 "
			VENUS.		
Feb. 23........	19 17.8	− 19 40	4 23 A. M.	9 04.8 A. M.	1 47 P. M.
Mar. 5........	20 03.6	− 18 40	4 25 "	9 11.3 "	1 58 "
15........	20 49.9	− 16 48	4 23 "	9 18.0 "	2 13 "
			MARS.		
Feb. 23........	1 17.4	− 8 13	8 30 A. M.	3 03.6 P. M.	9 42 P. M.
Mar. 5........	1 44.4	+ 10 59	8 04 "	2 51.2 "	9 39 "
15........	2 11.7	+ 13 34	7 41 "	2 39.1 "	9 38 "
			JUPITER.		
Feb. 23........	21 57.3	− 13 19	6 35 A. M.	11 45.0 A. M.	4 55 P. M.
Mar. 5........	22 06.5	− 12 31	6 02 "	11 14.8 "	4 28 "
15........	22 15.5	− 11 42	5 28 "	10 44.4 "	4 01 "
			SATURN.		
Feb. 23........	11 06.1	+ 8 07	6 15 P. M.	12 50.6 A. M.	7 26 A. M.
Mar. 5........	11 03.2	+ 8 26	5 32 "	12 08.4 "	6 45 "
15........	11 00.2	+ 8 44	4 48 "	11 26.1 P. M.	6 04 "

Date. 1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			URANUS.		
Feb. 23	13 57.1	− 11 23	10 23 P. M.	3 41.1 A. M.	8 59 A. M.
Mar. 5	13 56.3	− 11 18	9 43 "	3 01.0 "	8 19 "
15	13 55.2	− 11 12	9 02 "	2 20.6 "	7 39 A. M.
			NEPTUNE.		
Feb. 23	4 09.4	+ 19 23	10 31 A. M.	5 55.1 P. M.	1 20 A. M.
Mar. 5	4 09.8	+ 19 25	9 51 "	5 16.1 "	12 41 "
15	4 10.3	+ 19 27	9 12 "	4 37.4 "	12 02 "
			THE SUN.		
Feb. 18	22 07.7	− 11 32	6 56 A. M.	12 14.1 P. M.	5 32 P. M.
23	22 26.9	− 9 44	6 48 "	12 13.5 "	5 39 "
28	22 45.8	− 7 52	6 40 "	12 12.7 "	5 46 "
Mar. 5	23 04.5	− 5 57	6 31 "	12 11.6 "	5 53 "
10	23 23.0	− 4 00	6 22 "	12 10.4 "	5 59 "
15	23 41.3	− 2 02	6 13 "	12 09.0 "	6 05 "
			THE MOON.		
Feb. 24	11 41.6	+ 7 17	6 36 P. M.	1 22.5 A. M.	7 58 A. M.
28	14 43.5	+ 13 27	10 48 "	4 08.0 "	9 19 "
Mar. 5	18 29.7	− 25 35	3 18 A. M.	7 38.0 "	11 57 "
10	23 45.9	− 6 48	6 53 "	12 33.7 P. M.	6 17 P. M.
15	4 26.1	+ 21 42	9 09 "	4 53.6 "	12 48 A. M.

Phases and Aspects of the Moon.

			Central Time. d	h	m
First Quarter	1891	Feb.	15	12	29 P. M.
Apogee	"	"	23	Noon.	
Full Moon	"	"	23	9	18 P. M.
Last Quarter	"	Mar.	3	1	37 "
Perigee	"	"	9	6	40 "
New Moon	"	"	10	5	51 A. M.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N.P't. °	Duration. h m.
Feb. 17	132 Tauri	5.3	8 04	62	9 27.8	283	1 24
18	ε Geminorum	3.2	7 57	92	9 30.4	265	1 33
19	κ Geminorum	3.6	12 27	65	13 22.5	328	0 55
21	B.A.C. 3206	6.3	10 47	86	12 06.2	325	1 15
22	η Leonis	3.3	7 21	19	7 25.9	10	0 04
24	ν Virginis	4.0	12 59	85	14 03.0	350	1 09
Mar. 1	41 Librae	5.9	17 36	180	18 14.8	234	0 39

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.		ALGOL.		λ TAURI	
R. A.	$0^h\ 52^m\ 32^s$	R. A.	$3^h\ 01^m\ 01^s$	R. A.	$3^h\ 54^m\ 35^s$
Decl.	$+81°\ 17'$	Decl.	$+40°\ 32'$	Decl.	$+12°\ 11'$
Period	$2d\ 11^h\ 50^m$	Period	$2d\ 20^h\ 49^m$	Period	$3d\ 22^h\ 52^m$
Feb. 15	Midn.	Feb. 17	4 P. M.	Feb. 18	7 P. M.
22	11 P. M.	Mar. 1	3 A. M.	22	6 "
27	11 "	3	midn.	26	5 "
Mar. 4	11 "	6	9 P. M.	Mar. 2	4 "
9	10 "				
14	10 "				

R CANIS MAJ.

R. A. .... $7^h\ 14^m\ 30^s$
Decl. .... $-16°\ 11'$
Period .... $1d\ 3^h\ 16^m$

Feb.	21	7 P. M.
	22	10 "
	24	1 A. M.
Mar.	1	5 P. M.
	2	8 "
	3	midn.
	10	7 P. M.
	11	10 "

S. CANCRI.

R. A. .... $8^h\ 37^m\ 39^s$
Decl. .... $+19°\ 26'$
Period .... $9d\ 11^h\ 38^m$

Feb.	20	9 P. M.
Mar.	11	8 "

S ANTLIÆ.

R. A. .... $9^h\ 27^m\ 30^s$
Decl. .... $-28°\ 09'$
Period .... $7^h\ 47^m$

Feb.	18	midn.
	19	"
	20	11 P. M.

S. ANTLIÆ, *Cont.*

Feb.	21	10 P. M.
	22	10 "
	23	9 "
	24	8 "
	25	8 "
	26	7 "
Mar.	2	midn.
	3	"
	4	11 P. M.
	5	10 P. M.
	6	10 "
	7	9 "
	8	8 "
	9	8 "
	10	7 "
	11	6 "
	14	midn.
	15	11 P. M.

δ LIBRÆ.

R.A. .... $14^h\ 55^m\ 06^s$
Decl. .... $-8°\ 05'$
Period .... $2d\ 07^h\ 51^m$

Feb.	22	1 A. M.
Mar.	1	1 "
	7	midn.
	14	"

U CORONÆ.

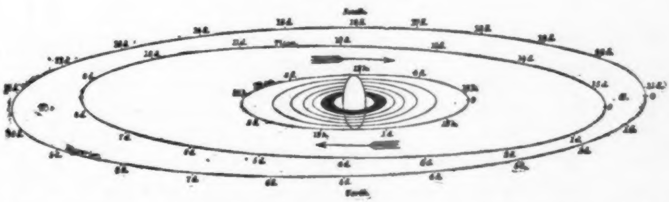
R. A. .... $15^h\ 13^m\ 43^s$
Decl. .... $+32°\ 03'$
Period .... $3d\ 10^h\ 51^m$

Feb.	19	10 P. M.
Mar.	9	4 A. M.

U OPHIUCHI.

R. A. .... $17^h\ 10^m\ 56^s$
Decl. .... $+1°\ 20'$
Period .... $0d\ 20^h\ 08^m$

Feb.	18	4 A. M.
	18	midn.
	23	5 A. M.
	24	1 "
	28	6 "
Mar.	1	2 "
	5	6 "
	6	2 "
	11	3 "
	11	11 P. M.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, MAY 17, 1891, AS SEEN IN AN INVERTING TELESCOPE.
(*The Vertical Scale is Twice the Horizontal One.*)

Mr. Marth's Ephemerides of Saturn's Satellites.

[Reduced to Central Time; from Monthly Notices, Vol. LI. Nov. 1890; Di = Dione; En. = Enceladus; Mi. = Mimas; Rh. = Rhea: Te. = Tethys; Ti. = Titan; c = conjunction with the center of planet; f = conjunction with following end of ring; p = conjunction with preceding end; n = north; s = south of the major axis of the ring; e = eastern elongation; w = western elongation.]

1891

Feb.	1	6.2 p.m.	Di. ps.
		7.0	Mi. fn.
		7.5	Te. pn.
		7.7	En. ps.
	2	12.9 a.m.	Mi. pn.
		1.9	Rh. fn.
		2.0	Di. fs.
		2.0	En. fs.
		3.3	Te. w.
		2.5 p.m.	Di. e.
		5.6	Mi. fn.
		6.1	Te. fs.
Feb.	3	6.5 p.m.	En. pn.
		11.5	Mi. pn.
	3	2.0 a.m.	Te. e.
		3.1	Di. fn.
		4.2 p.m.	Mi. fn.
		4.8	Te. pn.
		9.0	En. fn.
		10.1	Mi. pn.
		11.4	Di. w.
	4	12.6 a.m.	Te. w.
		3.3	En. pn.
		3.5	Mi. ps.
Feb.	4	3.4 p.m.	Te. fs.
		5.1	Rh. fs.
		7.7	Di. fs.
		7.8	En. fs.
		8.7	Mi. pn.
		11.3	Te. e.
	5	2.1 a.m.	Mi. ps.
		3.7 p.m.	Rh. e.
		7.2	Mi. pn.
		8.7	Di. fn.
		9.9	Te. w.
		10.3	En. ps.

Feb.	6	12.7 a.m.	Mi. ps.
		4.5	Di. pn.
		4.6	En. fs.
		3.2 p.m.	Tit. inf. c. n. 10"
		5.0	Di. w.
		6.0	Mi. pn.
		8.6	Te. e.
		9.1	En. pn.
		11.2	Rh. pn.
		11.4	Mi. ps.
	7	4.4 a.m.	Te. fn.
		4.6 p.m.	Mi. pn.
		7.2	Te. w.
		9.8	Rh. w.
		10.0	Mi. ps.
		11.6	En. fn.
	8	1.9 a.m.	Di. e.
		3.0	Te. ps.
		4.0 p.m.	En. ps.
		5.8	Te. e.
		8.4	Rh. ps.
		8.6	Mi. ps.
		10.2	Di. pn.
		10.4	En. fs.
	9	1.7 a.m.	Te. fn.
		2.5	Mi. fs.
		2.8 p.m.	En. pn.
		4.5	Te. w.
		7.2	Mi. ps.
		11.2	Di. ps.
	10	12.3 a.m.	Te. ps.
		12.9	En. ps.
		1.1	Mi. fs.
		3.1 p.m.	Te. e.
		5.4	En. fn.
		5.8	Mi. ps.
		7.5	Di. e.
		10.0	Te. fn.
		10.7	En. pn.
		10.7	Mi. fs.
	11	2.6 a.m.	Rh. fn.
		1.8 p.m.	Te. w.
		3.8	Di. pn.
		4.2	En. fs.
		4.4	Mi. ps.
		9.6	Te. ps.
		10.3	Mi. fs.
	12	2.2 a.m.	En. fn.
		3.7	Mi. fn.
		4.3	Di. w.
		4.6	Te. fs.
		4.8 p.m.	Di. ps.
		6.7	En. ps.
		8.2	Te. fn.
		8.9	Mi. fs.
	13	12.6 a.m.	Di. fs.
		1.0	En. fs.
		2.3	Mi. fn.
		3.2	Te. pn.
		5.5 p.m.	En. pn.
		5.7	Rh. fs.
		6.9	Te. ps.
		7.6	Mi. fs.
	14	1.0 a.m.	Mi. fn.
		1.7	Di. fn.
		1.9	Te. fs.
		3.5	En. ps.
		4.3 p.m.	Rh. e.
		5.5	Te. fn.
		6.2	Mi. fs.
		8.0	En. fn.
		8.6	Tit. sup. c. s. 12"
		10.0	Di. w.
		11.6	Mi. fn.
	15	12.5 a.m.	Te. pn.
		2.4	En. pn.
		2.9 p.m.	Rh. fn.
		4.2	Te. ps.
		4.8	Mi. fs.
		6.3	Di. fs.
Feb.	15	6.8 p.m.	En. fs.
		10.2	Mi. fn.
		10.7	Te. fs.
		11.9	Rh. pn.
	16	4.1 a.m.	Mi. pn.
		4.9	En. fn.
		2.9 p.m.	Te. fn.
		3.4	Mi. fs.
		7.3	Di. fn.
		8.8	Mi. fn.
		9.3	En. ps.
		9.9	Te. pn.
		10.5	Rh. w.
	17	2.7 a.m.	Mi. pn.
		3.1	Di. pn.
		3.7	En. fs.
		3.6 p.m.	Di. w.
		7.4	Mi. fn.
		8.1	En. pn.
		8.5	Te. fs.
		9.1	Rh. ps.
	18	1.3 a.m.	Mi. pn.
		4.2	Di. ps.
		4.3	Te. e.
		6.0 p.m.	Mi. fn.
		7.1	Te. pn.
		10.6	En. fn.
		11.9	Mi. pn.
	19	12.5 a.m.	Di. e.
		2.9	Te. w.
		4.7	Rh. e.
		3.1 p.m.	En. ps.
		4.6	Mi. fn.
		5.8	Te. fs.
		8.8	Di. pn.
		9.4	En. fs.
		10.5	Mi. pn.
	20	1.6 a.m.	Te. e.
		3.2	Rh. fn.
		3.2 p.m.	Mi. fn.
		4.4	Te. pn.
		9.2	Mi. pn.
		9.8	Di. ps.
		11.9	En. ps.
	21	12.2 a.m.	Te. w.
		2.6	Mi. ps.
		3.1 p.m.	Te. fs.
		4.4	En. fn.
		6.1	Di. e.
		7.8	Mi. pn.
		10.7	En. pn.
		10.9	Te. e.
	22	1.2 a.m.	Mi. ps.
		12.9 p.m.	Tit. inf. c. n. 12".
		1.7 p.m.	Te. pn.
		2.4	Di. pn.
		3.2	En. fs.
		6.4	Rh. fs.
		6.4	Mi. pn
		9.5	Te. w.
	23	3.5	Di. ps.
		5.0	Rh. e.
		8.2	Te. e.
	24	3.6	Rh. fn.
		3.6	Mi. fn.
		4.5	En. pn.
		6.8	Te. w.
		9.0	Mi. ps.
	25	12.3 a.m.	Di. fn.
		12.6	Rh. pn.
		2.6	En. ps.
		2.6	Te. ps.
		2.9	Mi. fs.
		5.5 p.m.	Te. e.
		7.0	En. fn.
		7.6	Mi. ps.
		8.6	Di. w.
		11.1	Rh. w.
	26	1.3 a.m.	Te. fn.
		1.4	En. pn.
		1.5	Mi. fs.
Feb.	26	4.1 p.m.	Te. w.
		4.9	Di. fs.
		5.8	En. fs.
		6.2	Mi. ps.
		9.7	Rh. ps.
		11.9	Te. ps.
	27	12.1 a.m.	Mi. fs.
		3.9	En. fn.
		2.8 p.m.	Te. e.
		4.9	Mi. ps.
		5.9	Di. fn.
		8.3	En. ps.
		10.6	Te. fn.
		10.8	Mi. fs.
	28	1.7 a.m.	Di. pn.
		2.7	En. fs.
		1.4 p.m.	Te. w.
		2.2	Di. w.
		3.5	Mi. ps.
		7.1	En. pn.
		9.2	Te. ps.
		9.4 p.m.	Mi. fs.
Mar.	1	2.8 a.m.	Di. ps.
		2.8	Mi. fn.
		3.9	Rh. fn.
		4.2	Te. fs.
		12.0 m.	Te. e.
		12.9 p.m.	Rh. pn.
		2.1	Mi. ps.
		7.9	Te. fn.
		8.0	Mi. fs.
		9.6	En. fn.
		11.1	Di. e.
	2	1.4 a.m.	Mi. fn.
		2.9	Te. pn.
		4.0	En. pn.
		2.1 p.m.	En. ps.
		6.2	Tit. sup. c. s. 14"
		6.5	Te. ps.
		6.6	Mi. fs.
		7.4	Di. pn.
		8.4	En. fs.
		12.0 midn.	Mi. fn.
	3	1.5 a.m.	Te. fs.
		12.9 p.m.	En. pn.
		5.2	Te. fn.
		5.2	Mi. fs.
		7.0	Rh. fs.
		8.4	Di. ps.
		10.6	Mi. fn.
		10.9	En. ps.
	4	12.2 a.m.	Te. pn.
		2.2	Di. fs.
		3.4 p.m.	En. fn.
		3.8	Te. ps.
		3.8	Mi. fs.
		4.7	Di. e.
		5.6	Rh. e.
		9.2	Mi. fn.
		9.7	En. pn.
		10.8	Te. fs.
	5	3.1 a.m.	Mi. pn.
		1.0 p.m.	Di. pn.
		2.2	En. fs.
		2.4	Te. fn.
		2.4	Mi. fs.
		4.2	Rh. fn.
		7.8	Mi. fn.
		9.4	Te. pn.
	6	12.3 a.m.	En. fn.
		1.2	Rh pn.
		1.5	Di. w.
		1.8	Mi. pn.
		1.0 p.m.	Mi. fs.
		1.1	Te. ps.
		2.1	Di. ps.
		4.7	En. ps.
		6.5	Mi. fn.

COMET NOTES.

Periodic Comets due in 1891.—Four periodic comets are due this year. All are telescopic, and all but one have been observed at more than one apparition.

Tempel's first periodical comet, discovered by Temple in 1867, is due in April unless its period has been changed by perturbations since 1879. It was observed in 1873 and 1879 but escaped detection in 1885. The period is a few days less than six years.

Wolf's comet, 1884 III, was found by Thraen (*Astr. Nach.*, 2790 p. 97) to have a period of 6.775 years. It should be at perihelion in August, 1891. There is some uncertainty, however, about the elements, so that the comet may appear earlier or later than the designated time.

Swift's comet, 1880 V, known now as Temple-Swift's, is due at perihelion in October. Its period is 5.50 years. It was first observed by Tempel in 1869, and is unfavorably situated for observation at alternate returns to perihelion. It probably will not be detected this year.

Encke's comet is due in the same month, October. This comet has been seen at every return since Encke determined its period in 1818-19. The problem of the "resisting medium" or the cause of the gradual diminution of the period of this comet has not been satisfactorily solved, so that much interest still attaches to the successive apparitions.

Comet 1890......(Spitaler Nov. 16)—Dr. Spitaler has computed the elements of this comet from his own observations of Nov. 16, Dec. 4 and Dec. 13 (*Astr. Nach.* 3009), and finds that the orbit is not parabolic. Mr. Rosmanith computed the following elliptic elements, which show that the comet is one of short period.

$$\begin{aligned} T &= 1890 \text{ Oct, } 26.50833 \text{ Berlin M. T.} \\ \left.\begin{aligned} \pi &= 58^\circ\ 24'\ 28.2'' \\ \Omega &= 45\ \ 07\ \ 51.2 \\ i &= 12\ \ 51\ \ 49.0 \end{aligned}\right\} & \ 1890.0 \\ \varphi &= 28\ \ 11\ \ 26.6 \\ \log a &= 0.537532. \qquad a = 3.4477. \\ \mu &= 554.2'' \\ \text{Period} &= 6.4 \text{ Years.} \end{aligned}$$

The perihelion distance is 1.819 and the aphelion distance 5.076 times the earth's distance from the sun. The comet is so faint as to be seen only with telescopes of very large aperture. In *Astr. Nach.* 3010, Dr. Spitaler suggests that the comet has described this orbit only since 1887, for in the latter part of that year it was at its descending node very near to Jupiter, and probably suffered great perturbations.

Zona's Comet will be almost stationary in right ascension and declination during the month of February. Its place is about 5° west and a little north of Alpha Arietis in the head of The Ram. Its theoretical brightness is less than one fifth that which it had when discovered.

Ephemeris of Comet e 1890 (Zona Nov. 15). From the elements of my orbit as given in the "SIDEREAL MESSENGER" for January I have computed the following ephemeris:

Gr. M. T.	App. R. A. h m s	App. Dec. ° ′	Log *r*.	Log Δ.
Feb. 1.5	1 31 30	+ 25 44		
2.5	31 15	25 41	0.4652	0.4737
3.5	31 0	25 38		
4.5	30 45	25 36		
5.5	30 32	25 34		
6.5	30 19	25 32	0.4699	0.4889
7.5	30 7	25 30		
8.5	29 56	25 28		
9.5	29 46	25 26		
10.5	29 38	25 24	0.4745	0.5038
11.5	29 32	25 22		
12.5	29 26	25 21		
13.5	29 21	25 20		
14.5	29 18	25 19	0.4791	0.5179
15.5	29 16	25 18		
16.5	29 15	25 17		
17.5	29 15	25 17		
18.5	29 16	25 16	0.4836	0 5312
19.5	29 18	25 16		
20.5	29 21	25 16		
21.5	29 25	25 16		
22.5	29 29	25 16	0.4882	0.5438
23.5	29 34	25 16		
24.5	29 40	25 16		
25.5	29 47	25 17		
26.5	29 55	25 17	0.4927	0.5556
27.5	30 4	25 17		
28.5	1 30 14	+ 25 18		

The theoretical light of the comet on Feb. 28 will be less than half that on Feb. 1.

O. C. WENDELL.

Harvard College Observatory, Jan. 14, 1891.

Carleton College Sun-spot Observations. (Continned from page 37.)

Date 1890.	Central Time.	Groups.	Spots.	Faculæ.	Observer.	Remarks.
Dec. 23	12.40 p m	1	1	2 gr.	C. R. W.	Faculae W.
24	2.15 "	1	4	2 "	H. C. W.	Faculae W.
27	11.00 a m	1	3	1 "	"	Faculae E.
30	12.00 "	1	1	1 "	"	Faculae N W.
1891.						
Jan. 2	12.00 "	0	0		"	
3	12.00 "	0	0		"	
5	2.00 p m	0	0	3 "	"	
7	2.45 "	1	4	1 "	C. R. W.	Large gr. of fac. E. Spots small.
8	12.40 "	1	2	1 "	"	
13	12.30 "	0	0	0 "	"	
14	10.05 a m	0	0	0 "	"	
15	12.25 p m	1	1	1 "	"	Large spot E.
17	12 45 "	1	4		"	
19	10.30 a m	2	4	1 "	"	Two small spots N. W. One large and one small spot S. E. Faculae E.
20	2.45 p m	2	5	1 "	"	

Smith Observatory Solar Observations. The following were observed with the helioscope unless otherwise specified:

1890-1.	90 Merid M. T.	Groups.	Spots.	Faculæ.	Seeing.	REMARKS.
Dec. 17	3.30 p m	1	7	0	poor.	Gran. fine.
18	9.30 a m	2	15	0	poor.	Group near N.E. and S.W. limbs.
19	3.45 p m	2	4	0	poor.*	Glimpsed for a moment in clouds.
21	3.00 "	2	2	0	fair.*	Gran. plain; fac. about each group.
23	1.25 "	0	0	0	fair.	Gran. fair.
27	11.00 a m	1	4	0	fair.	Gran. good.
29	10.00 "	1	4	2	fair.*	Fac. N.W. limb and around spots.
30	2.00 p m	1	3	1	poor.	Fac. N.W. limb.
Jan. 3	4.00 "	0	0	0	bad.	Bad definition.
4	1.00 "	0	0	0	poor.	Bad definition.
5	2.30 "	0	0	2	fair.	Fac. near E. and W. limbs.
6	11.45 a m	0	0	1	fair.	Suspected spots forming N.E. large. gr. fac S. E.
7	11.15 "	2	?	1	poor.	Could not count spots (3 in N.E. gr.?)
8	9.30 "	0	0	0	bad.	Could distinguish nothing.
9	11.30 "	0	0	0	fair.	Gran. fair.
13	11.40 "	0	0	0	poor.	Definition poor, high wind.
14	11.15 "	0	0	0	bad.	Could distinguish nothing.
15	12.00 m	1	1	2	good.	Fac. around spot and also north of it.
17	1.45 p m	3	9	1	good.	Large typical spot; penumbra finely marked.
18	3.30 "	4	4	1	poor.	Impossible to count spots in one group.
19	10.00 a m	5	14	1	good.	At 12 m. 2 small spots had appeared in fac. group; at 1.30 a new spot just outside penumbra of large spot; unusual activity.

* Projection on 20 cm. circle.

Belolt, Wis., 20 Jan., 1891. CHAS. A. BACON.

Interesting Phenomena. Under date of Jan. 12, Professor C. M. Charroppin, S. J., of St. Charles, Mo., writes concerning interesting phenomena observed in his locality. On the evening of Jan. 4, at 6 o'clock, at an altitude of 35° or 40° southeast of Polaris, a very luminous object was seen. Those who observed it claim that it looked like the tail of a comet, though much brighter, and of a reddish hue. Though Professor Charroppin did not see the object, he thinks, from the description of others, that it was elliptical in shape, with major axis vertical, and probably occupying 40′ or 50′ of arc; that it was stationary and continued for five minutes, and then disappeared. He is unable to give a satisfactory explanation of the phenomenon, and suggests that other readers of THE MESSENGER may have seen it.

He further says that on the 18th of December he was at the Observatory of Capt. Petitdedier, who has a 12-inch reflector made by himself. The night was fair, and the six stars in the Trapezium or θ Orionis appeared distinctly with a power of 300. The moon was nearing first quarter and had just passed culmination. The mirror of the instrument being well corrected gave no color whatever. Mons Christi was just looming up beyond the terminator. The peak was very bright, and showed some of the prismatic colors. It appeared to Professor Charroppin and his friend, the captain, like the reflection of the morning sun striking a mountain covered with icicles. Different eye-pieces were tried with the same result. No sign of color could be seen on any other mountain of the moon. This high peak was the only one then visible beyond the terminator.

As Professor Charroppin is inclined to favor the theory that the moon is covered with ice and snow; he is, of course, interested to know if others have made the same observations.

NEWS AND NOTES.

It is taken for granted that subscribers who have not renewed or signified a wish for the continuance of THE MESSENGER prefer that it should be stopped, and we have done so. In passing names to a new book mistakes may have been made. Errors will be promptly corrected if friends will notify us.

To present Dr. Huggins' valuable paper as a whole, and to give place to other important new matter, we have added sixteen pages to this number more than usual. The definitive work of the spectroscope rightly claims large place in an account of the progress of astronomy at the present time.

We notice with pleasure that a full account of James E. Keeler's study of Jupiter during the year 1889 has been published in German in *Himmel und Erde*. The reproduction of his eight drawings of the surface markings of the planet is admirable.

Although we have added much to our space this time, we have not found room for considerable matter to aid in the study of the constellations which has been already proposed. It was our plan to present this month, a map of the constellation of Orion and call attention first to features readily seen by the naked eye, then further study by the opera-glass, and finally notice the work done by telescopes, large and small. We are not sure that such an outline study will be very useful, but it will be tried in the hope that it will elicit comment from those interested, when it appears, to guide us in further attempts of a similar kind.

Foreign subscribers will please remember that the post office at Northfield is not a foreign money order office. All foreign money orders in favor of the MESSENGER should be drawn on the post office at St. Paul or at Faribault.

With great regret a little while ago we learned of the affliction of Professor Daniel Kirkwood, of Riverside, California, in the sudden death of his wife, by heart failure, which occurred Nov. 8, 1890. It is indeed a beautiful and a brave spirit that can say, as he did, in such trying circumstances, "The Lord gave and the Lord hath taken away."

Dresden Astronomical Observations. Three very neat volumes of astronomical observations, in quarto form, have been received from B. D'Englehardt, of Dresden. One volume was issued in 1886 and the other two for 1890. The first part for last year contains micrometrical observations of the satellites of Saturn, observations of planets and comets, double stars of Bradley, and other important lists made mainly since 1887. The second volume gives a description of the astronomical instruments and buildings of the Observatory at Dresden.

Astronomical Expedition to Peru. Professor William H. Pickering sailed from New York for Arequipa, Peru, on December 20, accompanied by Mr. A. E. Douglas and Mr. R. D. Vickers, who will assist him in his astronomical work. The Harvard College Observatory has, until recently, occupied a station on Mount Harvard, near Chosica, in Peru, where under the direction of the Messrs. Bailey, photographs of the southern heavens have been obtained with the Bache photographic telescope, aperture 8 inches, focal length 44 inches. Measures of the light of the bright and faint stars have also been made with the meridian photometer. These measures will furnish the material for determining the magnitudes of the southern stars brighter than the magnitude 6.3, and thus extending the "Harvard Photometry" to the South Pole. Measures have also been obtained of stars of the ninth magnitude and brighter, distributed in zones similar to those recently published in Vol. XXIV of the H. C. O. Annals. In consequence of the long duration of the rainy season at Mount Harvard, the instruments have been removed to Arequipa, which has an elevation of about 8,000 feet above the sea level, where a station has been established. There, under the direction of Professor W. H. Pickering, the photometric observations will be completed and the work of the Bache telescope continued and extended. The plan of work for this instrument is to cover the sky from —20° to the south pole; first with chart plates having 10 minutes' exposure; second with chart plates having 60 minutes' exposure; third with spectrum plates having 10 minutes' exposure; and fourth with spectrum plates having 60 minutes' exposure. Each of these researches will cover the sky twice, so that at least eight photographs of every bright star will be obtained. It is further proposed that, while the instrument remains in Peru, the first of this series of plates be repeated each year, in order to furnish a means of determining and discussing variability or large proper motion in the stars. Professor Pickering has taken with him the Boyden photographic telescope, aperture 13 inches, which, until lately, has been employed in photographing the objects of interest in the heavens which could be advantageously obtained at the station on Wilson's peak in southern California. With this instrument he will continue to photograph the moon, planets, double stars, clusters and nebulae. In addition to this, by placing a prism over the object glass, the spectra of the brighter southern stars will be obtained with this instrument, on a scale which will render the photographs comparable with those of the northern stars obtained with the 11-inch Draper telescope at Cambridge, thus extending this important investigation also from pole to pole. A meteorological station will be attached to the Observatory at Arequipa, which will furnish interesting records of atmospheric conditions prevailing at this elevation. The series of meteorological observations at Vinconcaya, elevation, 14,600 feet; at Puno, elevation 12,500 feet; and at Mollendo, near the sea level, will also be continued. The Messrs. Bailey, who at present have charge of the observing station at Arequipa, will probably return to Cambridge in April, bringing with them the meridian photometer.

Professor W. A. Crusenberry, of Drake University, Des Moines, Iowa, is planning for astronomical work and is getting a small telescope in place for it.

Stars Having Peculiar Spectra—New Variable Stars in Aquarius and Delphinus. [Communicated by Edward C. Pickering, Director of Harvard College Observatory.] Photographs of stellar spectra taken at the Harvard College Observatory, with the 8-inch Draper telescope, continue to add to the list of interesting objects in the heavens. On plate 2533, taken Dec. 19, 1890, the star D. M. $+63°$ 83, magn. 9.5, whose approximate position for 1900 is in R. A. 0^h 37.5^m, Decl. $+64°$ $14'$, shows a spectrum consisting mainly of bright lines, and similar to that of the Wolff and Rayet stars in Cygnus. On plate 2224 taken November 8, 1890, bright hydrogen lines are visible in the spectrum of a star whose approximate position for 1900 is in R. A. 20^h 41.2^m, Decl. $-4°$ $26'$. Chart plates of the region were examined which proved the variability of this star. The following approximate magnitudes were obtained, 8.6, 8.6, 8.4, 9.1, and 9.6, on Oct. 18, Nov. 8, Nov. 13, Dec. 12, and Dec. 15, 1890. Another variable star, having a similar spectrum, was found on plate 2542, taken Dec. 20, 1890. Its approximate position for 1900 is in R. A. 20^h 43.1^m, Decl. $+18°$ $58'$. Chart plates of this region were also examined, and the star was found to be fainter than the tenth magnitude on June 30, July 29, Aug. 15, Sept. 25, Sept. 29, Oct. 11, and Oct. 28, 1890, while on Nov. 28, Dec. 19, and Dec. 22, 1890, it had the approximate magnitudes 9.3, 8.6, and 8.7. M. FLEMING.

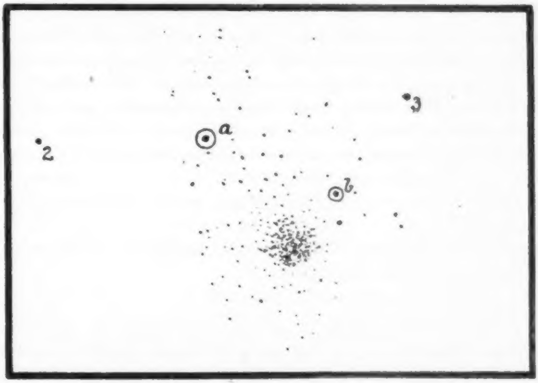
Harvard College Observatory, Cambridge, Mass., Jan. 13, 1891.

Honors for Professor C. A. Young. The readers of THE MESSENGER will be interested to learn that the Janssen prize for 1890 by the French Academy of Sciences has been awarded to Professor Charles A. Young, of Princeton, for his discoveries in spectroscopy.

The Explosion of a Meteor. The *Ohio State Journal*, Dec. 20, 1890, contains a brief account of the explosion of a meteor near Utica, Ohio, at 9 o'clock on the evening of December 18. The concussion was noticed by many people and was preceded by a bright red light which illuminated the sky in the direction of northwest. Persons residing about three miles northwest of Utica say the shock was "stunning" in that vicinity. At Utica two distinct shocks were felt, the first slight, the second, after an interval of a few minutes strong enough to shake houses. The tremor was like an earthquake. Professor John Haywood, of Otterbein University, Westerville, Ohio, situated about 25 miles southwest from Utica, says he saw a light through the north window of a building where he happened to be at the time. Other persons at Westerville saw the light and heard a report which they supposed to be thunder. We hope to get a fuller report of these phenomena in the near future.

A Correction. It is sometimes dangerous to correct one error, as in opening your mouth to do it you may let slip another. That is what I did last month in saying incidentally that Sirius is 60 times our sun in mass. The statement would be improved by a decimal point after the 6. Error of one (1) in the characteristic of the logarithm! The school-boy who committed it is digraced and discharged. N. M. MANN.

New Variable Stars near the Cluster 5 M Libræ. Through some unaccountable oversight I omitted mentioning my observation upon another star, the south component of a wide pair just following the cluster. In the *Astr. Nachr.*, No. 2986, Professor Pickering communicates a note by Mrs. Fleming fully confirming the variability of both stars from a careful discussion of seventeen photographic plates at Harvard College Observatory. The following are the resulting light ranges and magnitudes: For the star s. preceding the cluster (marked *a* in the chart) a variation of 1.9 mag. is found, from 9.7 to 11.6, and for the star immediately s. following the cluster (marked *b* in the chart) a variation of 2.9 mag. is found, from 9.3 to 12.2, while the comparison stars used (marked 1, 2, and 3) are of magnitudes 9.5, 11.0, and 12.2 respectively. The accompanying chart is identical with one taken on the night of June 9th, and will serve to identify



THE VARIABLE STARS AROUND 5 M LIBRÆ.

these mysterious objects and their comparison stars excepting No. 1, which is 18′ or 20′ south of cluster and preceding the bright star 5 Serpentis; hence it cannot be included.

The cluster 5 Messier is one of the most beautiful of its kind, and easily resolvable with a moderate aperture, and from its position, well situated for observation in both hemispheres. The existence, therefore, of two new variables among the brightest of its outlying stars will considerably enhance its interest, and affords another instance of the association of variable stars with dense star clusters. D. E. PACKER.

London, 1890, Nov. 10.

T. J. J. See, Student in Astronomy at the University of Berlin, Prussia, has kindly furnished us with an outline of the mathematical work and a drawing showing the results of his new theory as applied to the system of γ Virginis. His paper on the eccentricity of the orbits of binary stars, elsewhere printed in this issue, gives the principal points of the theory.

Photographic Notes.—A body known as the American Photographic Conference has been recently organized in New York city. The conference proposes to establish a photographic institute where instruction will be given in various branches of photographic work.

A photographic plate, exposed in Algiers, has brought out 4,800 stars in the region of the nebulous spot in the constellation Lyra. The plate took a record of 3 square degrees.

The Harvard Peru expedition is about to be reinforced by the arrival of improved instruments. Among these instruments is a new photographic telescope of twenty-four inches aperture.

In the November number of Monthly Notices of the Royal Astronomical Society, Mr. H. C. Russell, writing of celestial photographs taken at the Sydney Observatory, makes the following statement: "Certain it is that these pictures present the Milky Way in an entirely new light, quite different from the telescopic or naked-eye view, and give it such a different aspect that the question arises which are we to accept? It seems evident that the photograph may be made to present the stars to us under an aspect quite different from that presented to the eye, because, by continued exposure, the faint stars may have time to produce as much effect as brighter stars, because the effect is limited by the amount of silver in the film, which, when altered by the bright star, stops any further effect of that star, while the faint ones may go on piling up their effect."

In the same publication Mr. Russell has a paper on "Electrical Control of Drive Clocks."

Knowledge, of January, contains two beautiful photographs of the sun's surface taken by Dr. Jules Janssen.

Albert Lea Scientific Association. The meeting of the Science Association at Albert Lea, Minn., on January 20, was largely attended. The paper that attracted special attention and which elicited cousiderable discussion was given by Mr. D. G. Parker, the theme being the Nebula Hypothesis. It was prepared for a popular audience. The first part of the address treated the subject historically and theoretically, giving attention chiefly to the principal points in proof of the support of the nebular theory. The last part deals with the weak points of the theory, and the modifications made by late writers to meet objections. The latter part of the theme will be presented at a subsequent meeting. Such papers and such popular gatherings are exceedingly helpful in lifting the common thought to a plane of activity and individual study from which must come only good results. Every small town ought to awaken and stimulate an interest in science for the common good. There is home ability enough for it if a few thoughtful persons will counsel together and plan to make use of it.

Astronomical Instruments. A recent catalogue of astronomical instruments by Jas. W. Queen and Company, of Philadelphia, has been received. We are agreeably surprised to find in it so large and varied a line of fine astronomical instruments. The showing for quality aud size of instruments is very creditable.

Meteor Radiants. I regret that in my article on Meteor Radiants I did not do full justice to Mr. Denning's unwearied assiduity as an observer. Some of his remarks led me to think that he had not watched during whole nights, but I find that they are susceptible of a different meaning. The only inference which I drew, however, was that a radiant which appeared to be isolated in Mr. Denning's Catalogue need not be so in reality, and this inference, I think, his own list of Stationary Radiants is sufficient to establish.

As to the charge of making "harassing attacks, etc.," on Mr. Denning, I may perhaps mention that my other letters, etc., to which he refers are written in the same tone as my article in THE SIDEREAL MESSENGER; and I would not have founded my conclusions almost exclusively on his catalogue if I did not entertain the highest opinion of his qualities as an observer. Whether I have attacked him or he has attacked me I leave your readers to judge; but I have no desire to retaliate.

His argument that because I am not myself an observer I have no right to form any theory about meteors seems to me a strange one. Are my friend Mr. Gore's orbits of double stars worthless because he has not (as perhaps he has not) ever measured the distance and position-angle for himself? But at all events Mr. Denning in his prefatory remarks to his catalogue throws down his facts—intimates that he has no theory to propound—and invites others to carry on the investigation. This I have endeavored to do, and for this endeavor I am denounced as an ignorant blunderer. This does not hold out a very inviting prospect to others who may feel disposed to enter on a branch of investigation indicated by Mr. Denning himself.

Mr. Denning seems in doubt as to what my views are. Permit me therefore briefly to relate them, leaving out some explanations which I always considered doubtful. They are: 1. Stationary or long-enduring radiants are not the exception but the rule, and this rule may even be an invariable law. 2. This being so, the connection between certain showers and certain comets cannot be so close as has hitherto been supposed. 3. No decided case of shifting in a radiant has as yet been established. Now on the first two of these propositions Mr. Denning has not in any of his attacks on me given a decided opinion, and he merely negatives the third by his *ipse dixit*. With this *ipse dixit* I should rest satisfied if the question was one of pure observation; but it plainly is not so. To establish the shifting of the Perseid radiant from $3° + 49°$ on the 8th of July to $78° + 58°$ on the 22d of August it would be necessary to set out all the radiants between $3° + 49°$ and $78° + 58°$ which were observed during the intervening time, to state the reasons for rejecting some of them as not being Perseids, and to show that, omitting these, the remainder exhibit a continuous change in R. A. and Decl. And even then observations made in other countries should be compared, seeing that during the great Andromede shower of 1885 Mr. Denning (supported by Col. Tupman) noticed a shifting in the direction of decreasing R. A., while Schiaparelli and Denza in Italy observed a shifting in the opposite direction. A radiant area, in which the point of maximum intensity varies with the conditions of time and place affords perhaps the best explanation of such phenomena.

Dublin, Dec. 13th, 1890. W. H. S. MONCK.

BOOK NOTICES.

New Light from Old Eclipses: or Chronology Corrected, and the Four Gospels Harmonized, by the Rectification of Errors in the received Astronomical Tables. By William M. Page. C. R. Barnes Publishing Co., St. Louis; 1890. pp. 590.

This book is evidently written by a seeker after truth and one who is actuated by a worthy purpose. The light sought is needed, and the way to the place where light dwells, as indicated by the writer, is not to be despised, for science is asked to aid where sacred chronology is in doubt. The use made, however, of the materials is open to objection, as must be easily seen by any careful reader able to judge of the facts. Let us look at a few instances:

The Introduction, consisting of ten pages, covers well the point of the uncertainty of early chronology from the best of historical sources. Then the question is asked, in the first chapter, have we any means outside of the testimony of ancient historians by which the three dates of the birth and crucifiction of Christ can be determined? The author answers affirmatively and seeks to prove his position by a study of the data of eclipses. He thinks the proof would be easy if existing astronomical tables were not so inaccurate; and hence his first duty is to show wherein and how much these tables are wrong, and he cites the differences between the successive lunar intervals of 1860 and 1861 as shown by Bailey's tables, and then says on pages 16 and 17 that because astronomers are not content with these observed errors they "have formulated a theory which adds to them," meaning of course the acceleration of the moon's mean motion. If we understand the author's meaning in this connection, we think he claims there is no such thing as a secular acceleration of the moon's mean motion. In this he is certainly wrong, for scarcely any fact in astronomy is better established than this. On pages 18 and 19 the author thinks that if the tables were changed a little, the calculation of certain early eclipses by them would be in accord with the times of their observation as recorded in history; but the chronology of history has before been declared wholly untrustworthy for definite results, and should the author now use its dates as an exact standard, by which to judge of the accuracy of his corrected tables? By so doing he treats well known facts of astronomy as false and sets aside, as of no consequence, some of the best work of which the master mind of Laplace was capable. We had always before given that renowned Frenchman the credit of knowing how "to do a sum in simple division in arithmetic." On page 27, it is said that the eclipses referred to do not prove the moon's acceleration, but, on the contrary, the errors of the tables. Evidently the author does not understand the elementary astronomy of this subject, or he never would have written this page. What has been discovered in astronomy is in perfect keeping with the laws of Nature generally, and the revealed will of God in the Bible, and when he says that God's "laws, whether for the regulation of the heavenly bodies or for the action of men, are forever the same," he certainly does not mean, as a believer in the Bible, to proclaim the eternity of material existence in its present form. If this is not the meaning of the paragraph we do not know

what it means. On page 28 the author assumes that astronomers are not as much interested in correct tables as they ought to be. We are sure he does not understand the facts, or he would not have made such a statement. At the bottom of the same page he says "the corrected tables, as seen below, make this eclipse (B. C. 481, April 19) to have taken place at nine minutes past six in the morning of April 19." The computation on page 30 gives that as the time of conjunction, but parallax is left out, and that alone would accelerate the eclipse by about two hours; the middle of an eclipse has a very loose connection with the time of conjunction. We have not space to pursue this study further except to call attention to a few more points:

P. 45, first paragraph, same error as before noted. Second paragraph the contrary is proved from that assumed. In the third paragraph the point claimed does not seem to us to be established by the Bible reference.

P. 47, the same reference unsatisfactory.

P. 49, same error as before noted.

P. 55, assumption in first paragraph unwarranted.

P. 56, the admission of the second paragraph is fatal.

In reading fifty pages we find what seems to us grievous errors numbering more than a score. Now we are sorry to find such a piece of work coming from the pen of a man whom good people, who know him, would gladly trust as an author, especially since another scholarly man of wide reputation has given added currency to this book by his explicit endorsement of it. True men ought to be more careful and not allow themselves to be caught in this way.

ONE LIFE; ONE LAW. By Mrs. Myron Reed, New York; John W. Lovell Company, 150 Worth Street, Corner Mission Place. pp. 223.

This is chiefly a book that deals with science, philosophy and religion. It has scarcely nothing to say about astronomy, and hence what we shall have to say of it must be in general terms through the eyes and mind of a layman, especially in regard to philosophy and religion and some of the sciences upon which it draws for its materials.

This book is divided into ten chapters with the following titles: The Word Spoken with Authority, The Power of Spirit, The Law of Natural Selection, Variations Under Four Heads: (1) The Struggle for Existence, (2) Inheritance, (3) Use and Disuse, (4) Surroundings; The Readiness for the New Kingdom, The Laws of the New Kingdom, The Character of Job and Prayer.

The first chapter sets out the principle of love and the authority that goes with it, and closes with the statement that *God is spirit, and spirit is all.* In the second chapter the power of the Spirit is spoken of, and the statement is made that "every obedient child goes through three distinct processes in his spiritual growth." At first, he recognizes in some measure the spirit he is of. This is the new birth which is a birth of consciousness. Then he enquires, 'What is God?' This question is in the province of philosophy, and here he must look for its answer. Having received one, he can not be sure of its authority, and asks, 'How can I prove that these things are true?" For answer he is directed to science, and in her domain he finds that GOD is divine principle working always by law."

We are not sure that we have the author's meaning in regard to what the new birth is. If by the new birth is meant the origin of consciousness as said on page 27, then certainly the Bible idea of this state of the human soul is a very different one, and wholly incompatible with it. If God is only Divine Principle, as we commonly use the word principle, then God is not a person; neither is there a personal agent acting as a cause to produce the new birth as an affect. That means that the whole question of sin, as understood in common Christian doctrine is at once read out of man's nature and all the wickedness of this life is not charged to the account of personal being at all. The consequences of such a belief are easily understood by those who believe in the cardinal doctrines of Christianity.

The chapter treating of the book of Job is just what might be expected from the views mentioned in previous ones. The book is treated as an epic poem, and the statement is made that "probably no Bible student of this day believes that a man by the name of Job ever lived in a land bearing the name of Uz." If we understand the expressed views of every leading evangelist of to-day that we know of, including D. L. Moody, that is exactly what they believe. Every believer in plenary inspiration, as it is called, must hold such views, and they do most conscientiously.

In the last chapter the need and office of prayer are not, as it appears to us, stated in such a way as to be consistent with previous positions. We have not space to speak of this at length. As a whole, the book is a neat specimen of the printers' art, and we wish as much could be said of the writer's part of it.

Upward Steps of Seventy Years. By Giles B. Stebbins. Publishers, Messrs; John A. Lovell Company, 142 to 150 Worth Street, New York City. pp. 308.

This book is autobiographic, biographic and historic. As a whole it is well written, and mingles, in rather pleasing way, the three-fold features of its story especially in its earlier chapters, barely intimating certain views entertained by the author which become more pronounced in the later ones. The reader is given to understand that Unitarianism and Universalism were the doctrines that brought broad, free ideas to the people who were under the narrow bondage of Puritanism, and on page 43 this sentence occurs: "Thus it became possible for Theodore Parker to stand before the largest Protestant audiences in Boston and preach in Music Hall for years, saying frankly and manfully that the Bible was a human book, valuable but fallible—to be judged by our reason, but never to be set up as authority over us. To-day liberal ministers, especially Unitarians, begin to take the same ground, and many of the people are in advance of most of the clergy." After finding such statments as the above, we are not surprised to find the author later avowing the belief of spiritualism, and treating its modern manifestations as a glorious and inspiring reform. Of course, the true believer has no controversy with such views. He pities the poor mortal who does not know any better than to put evil for good and light for darkness. A true Christian knows and constantly warns such deceived teachers of the consequences that will inevitably follow such a course. When we opened this book we hoped to find something better than we had found in some other books recently received; but in this we are disappointed. The book is wrongly titled.

Publishers' Notices.

BOOKS RECEIVED.

Tycho Brahe, a Picture of Scientific Life and Work in the Sixteenth Century, by J. L. E. Dreyer, Ph. D., F.R.A.S., Director of the Armagh Observatory. Messrs. Adam & Charles Black, Publishers, Edinburgh, Scotland. 1890.

A Treatise on Linear Differential Equations, by Thomas Craig, Ph. D., Vol. I. Equations with Uniform Co-efficients. Messrs. John Wiley & Sons, Publishers, 15 Astor Place. 1889.

A Treatise on Ordinary and Practical Differential Equations, by William Woolsey Johnson, Professor of Mathematics at the U. S. N. Academy, Annapolis, Maryland. Messrs. John Wiley & Sons, Publishers, 15 Astor Place. 1889.

Cosmical Evolution. A New Theory of the Mechanism of Nature, by Evan McLennan. Publishers, Messrs. Donohue, Henneberry & Co. 1890.

A School Algebra by G. A. Wentworth. Messrs. Ginn & Co., Publishers, Boston, Mass. 1890.

The New Theory of the Universe is the title of an article in the February Lippincott Magazine by Charles Morris, in which he argues that the old nebular theory of Kant and Laplace bids fair to become an outworn scientific creed, and that it will be replaced by a new theory bassed on meteoric aggregation. The two theories are contrasted and explained in a very interesting manner, and in such language that they may be readily understood by the unscientific reader.

Ella Wheeler Wilcox, Frank Dempster Sherman, Maurice Francis Egan, and other poets contribute to this number.

The Photographic Times of St. Louis, and Wilson's Photographic Magazine, of New York are the home publications which we constantly consult for latest information in the splendid photographic art.

The British Journal of Photography is one of our valued foreign exchanges and our many readers who are interested in photography will find very useful matter in each of its January issue.

A funny visitor looking at a picture of the great Lick Telescope the other day, wanted to know if it was called the Lick telescope because it 'licked' all others out in size.

A Great Railway.

The Chicago Millwaukee & St. Paul Railway Company now operates over sixty-one hundred miles of thoroughly equipped road in Illinois, Wisconsin, Northern Michigan, Minnesota, Iowa, Missouri, South and North Dakota. Each recurring year its lines are extended in all directions to meet the necessities of the rapidly populating sections of country west, northwest, and southwest, of Chicago, and to furnish a market for the products of the greatest agricultural and stock raising districts in the world. In Illinois it operates 317 miles of track; in Wisconsin 1,636 miles; in Northern Michi- 96 miles; in Iowa 1,551 miles; in Minnesota 1,115 miles, in South Dakota 1,092 miles; in North Dakota 118 miles; in Missouri 140 miles, and the end is not yet. It has terminals in such large cities as Chicago, Milwaukee, La Crosse, St. Paul, Minneapolis, Fargo, Sioux City. Council Bluffs, Omaha, and Kansas City and St. Joseph, Mo., and along its lines are hundreds of large and small thriving cities, towns and villages. Manufacturing interests are cultivated, and all branches of trade find encouragement. The Railway Company has a just appreciation of the value of its patrons, and its magnificent earnings are the result of the good business tact which characterizes the management of its affairs.

The popularity of the line is attested by the fact that notwithstanding the strongest kind of competition of old and new lines, the Chicago, Milwaukee & St. Paul Railway continues to carry the greater proportion of all the business between Chicago, Milwaukee, St. Paul and Minneapolis. It is the best patronized route between Chicago, Council Bluffs and Omaha to and from all points in Wisconsin. Minnesota, Dakota and Iowa, and its Kansas City and St. Joseph line has taken equal rank with the older lines leading to and from the Southwest.

On all its through lines of travel the Chicago, Milwaukee & St. Paul Railway runs the most perfectly equipped trains of Sleeping, Parlor and Dining Cars and Coaches. The through trains on all its lines are systematically heated by steam. No effort is spared to furnish the best accommodations for the least money, and, in addition, patrons of the road are sure of courteous treatment from its employes.